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STRUCTURES AND DYNAMICS DIVISION RESEARCH AND TECHNOLOGY PLANS FOR FY 1986 AND ACCOMPLISHMENTS FOR FY 1985

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

STRUCTURES AND DYNAMICS DIVISION

RESEARCH AND TECHNOLOGY PLANS FOR FY 1986

AND ACCOMPLISHMENTS FOR FY 1985

BY

KAY S. BALES

SUMMARY

The purpose of this report is to present the Structures and Dynamics Division's research plans for FY 1986 and accomplishments for FY 1985. The work under each branch is shown by RTR Objectives, FY 1986 Plans, Approach, Milestones, and FY 1985 Accomplishments. Logic charts show elements of research and rough relationship to each other. This information is useful in program coordination with other government organizations in areas of mutual interest.

ORGANIZATION

The Langley Research Center is organized by directorates as shown on figure 1. The Structures Directorate includes Structures and Dynamics Division, Materials Division, Loads and Aeroelasticity Division, and Acoustics Division. The Structures and Dynamics Division consists of four branches as shown on figure 2. There have been several significant changes in the organizational structure of the Division. Dr. Robert G. Thomson, Head, Impact Dynamics Branch, died in September 1985, and Mr. Harvey G. McComb, Jr., Assistant Chief, Structures and Dynamics Division, is currently Acting Head, Impact Dynamics Branch. Mr. John A. Tanner was selected as the Assistant Head, Impact Dynamics Branch. Mr. McComb also announced his retirement in 1986, and Dr. Larry D. Pinson, Head, Structural Dynamics Branch, was selected as Assistant Chief, Structures and Dynamics Division. Dr. Pinson also is currently Acting Head, Structural Dynamics Branch.

FUNCTIONAL STATEMENT

The Division conducts analytical and experimental research to achieve structures which meet functional requirements of advanced atmospheric and space flight vehicles. Provides experimental data and analytical methods for predicting stresses, deformations, structural strength, and dynamic response. Investigates interaction of structure with propulsion and control systems, landing dynamics, crash dynamics, and resulting structural response. Develops and evaluates structural

configurations embodying new material systems and/or advanced design concepts for general application and for specific classes or new aerospace vehicles. Develops advanced structural analysis methods and computer programs. Uses a broad spectrum of test facilities and develops new research techniques. Test facilities include the Structures and Materials Laboratory, Structural Dynamics Research Laboratory, Impact Dynamics Research Facility and the Aircraft Landing Dynamics Facility. Data are also obtained and analyzed from flight investigations.

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I ORGANIZATION CHARTS

LANGLEY RESEARCH CENTER

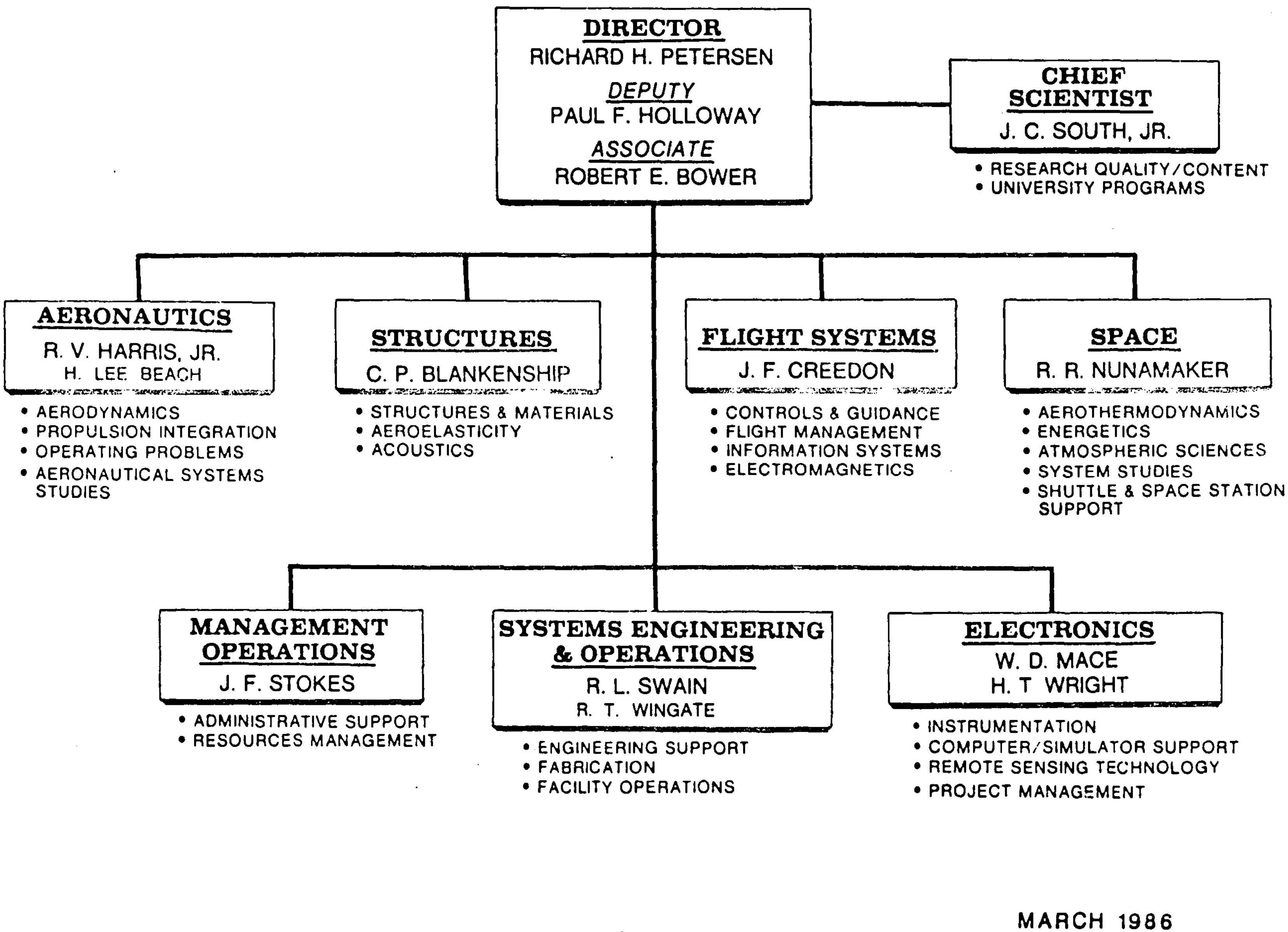


Figure 1.

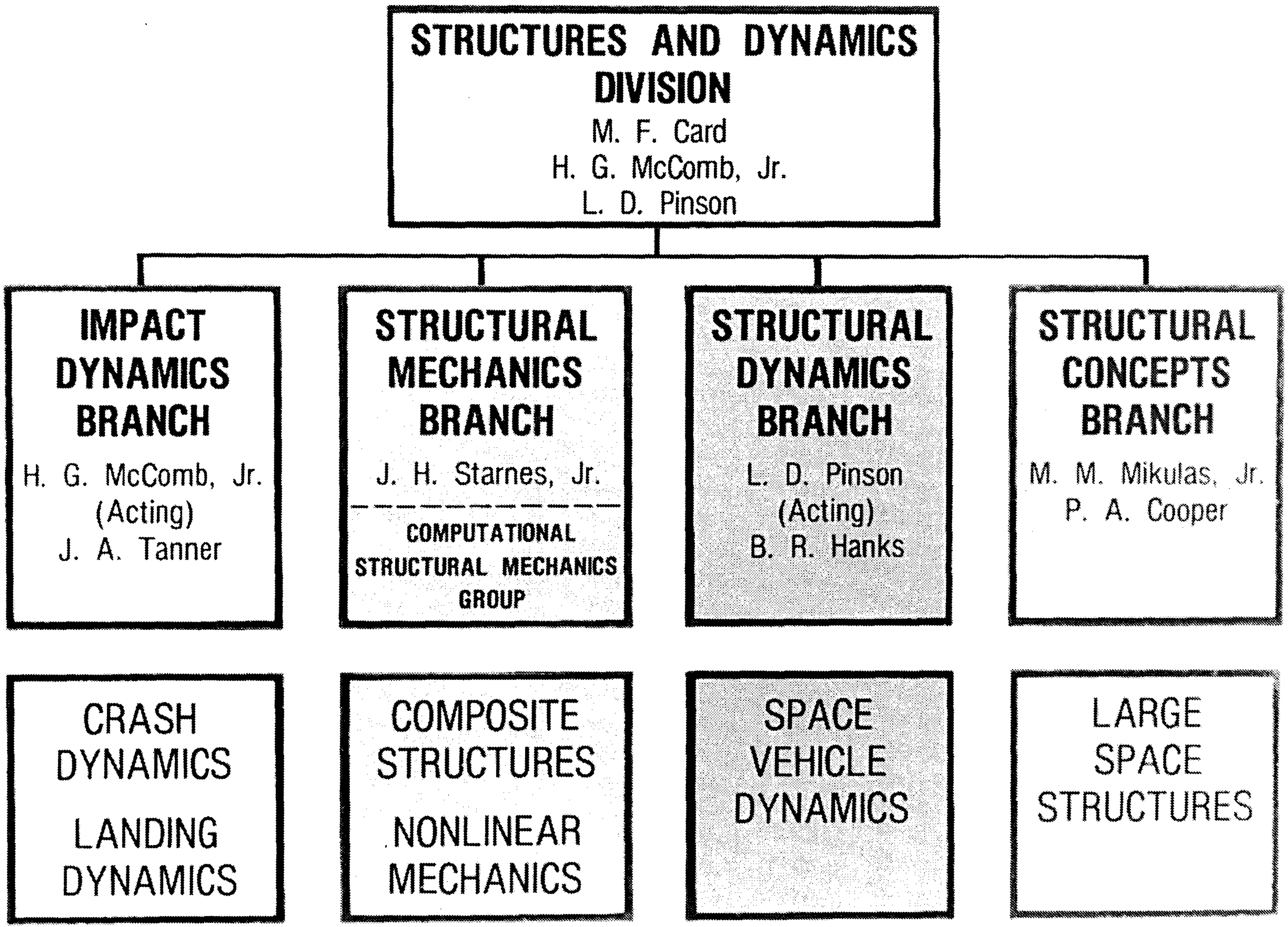

STRUCTURES AND DYNAMICS DIVISION
M. F. Card
H. G. McComb, Jr.
L. D. Pinson
IMPACT DYNAMICS BRANCH
H. G. McComb, Jr. (Acting)
J. A. Tanner
STRUCTURAL MECHANICS BRANCH
J. H. Starnes, Jr.
COMPUTATIONAL STRUCTURAL MECHANICS GROUP
STRUCTURAL DYNAMICS BRANCH
L. D. Pinson (Acting)
B. R. Hanks
STRUCTURAL CONCEPTS BRANCH
M. M. Mikulas, Jr.
P. A. Cooper
CRASH DYNAMICS
LANDING DYNAMICS
COMPOSITE STRUCTURES
NONLINEAR MECHANICS
SPACE VEHICLE DYNAMICS
LARGE SPACE STRUCTURES

Figure 2.

II FACILITIES

II FACILITIES

The Structures and Dynamics Division has four major facilities to support its research (shown in figure 3).

The Structures and Materials Laboratory equipment includes a 1,200,000 lbf capacity testing machine for tensile and compressive specimens up to 6 feet wide and 18 feet long; lower capacity testing machines of 300,000, 120,000, 100,000 and 10,000 lbf capacity; torsion machine of approximately 60,000 in.-lbf capacity; combined load testing machine; hydraulic and pneumatic pressurization equipment; and vertical abutment-type backstop for supporting and/or anchoring large structural test specimens.

The Impact Dynamics Research Facilities consist of the Aircraft Landing Dynamics Facility (ALDF) recently upgraded under a $15M CoF project, and the Impact Dynamics Research Facility. The ALDF consists of a rail system 2,800 ft. long x 30 ft. wide, a 2.0 Mlbs. thrust propulsion system, a test carriage capable of approximately 220 knots, and an arrestment system. A wide variety of runway surface conditions, ranging from dry and flooded concrete or asphalt to solid ice, can be duplicated in the track test section. In addition, unprepared surfaces such as clay or sod can be installed for tests to provide data on aircraft off-runway operations.

The Impact Dynamics Research Facility is capable of crash testing full-scale general aviation aircraft and helicopters under controlled conditions. Simulation is accomplished by swinging the aircraft by cables, pendulum-style, into the ground from an A-frame structure approximately 400 ft. long x 240 ft. high. A Vertical Test Apparatus is attached to one leg of the A-frame for drop-testing structural components.

The Structural Dynamics Research Laboratory is designed for carrying out research on spacecraft and aircraft structures, equipment, and materials under various environmental conditions, including vibration, shock, acceleration, thermal and vacuum. Equipment in the laboratory includes a 55-ft. (inside diameter) thermal vacuum chamber with a removable 5-ton crane, a flat floor 70 feet from the dome peak, and whirl tables.

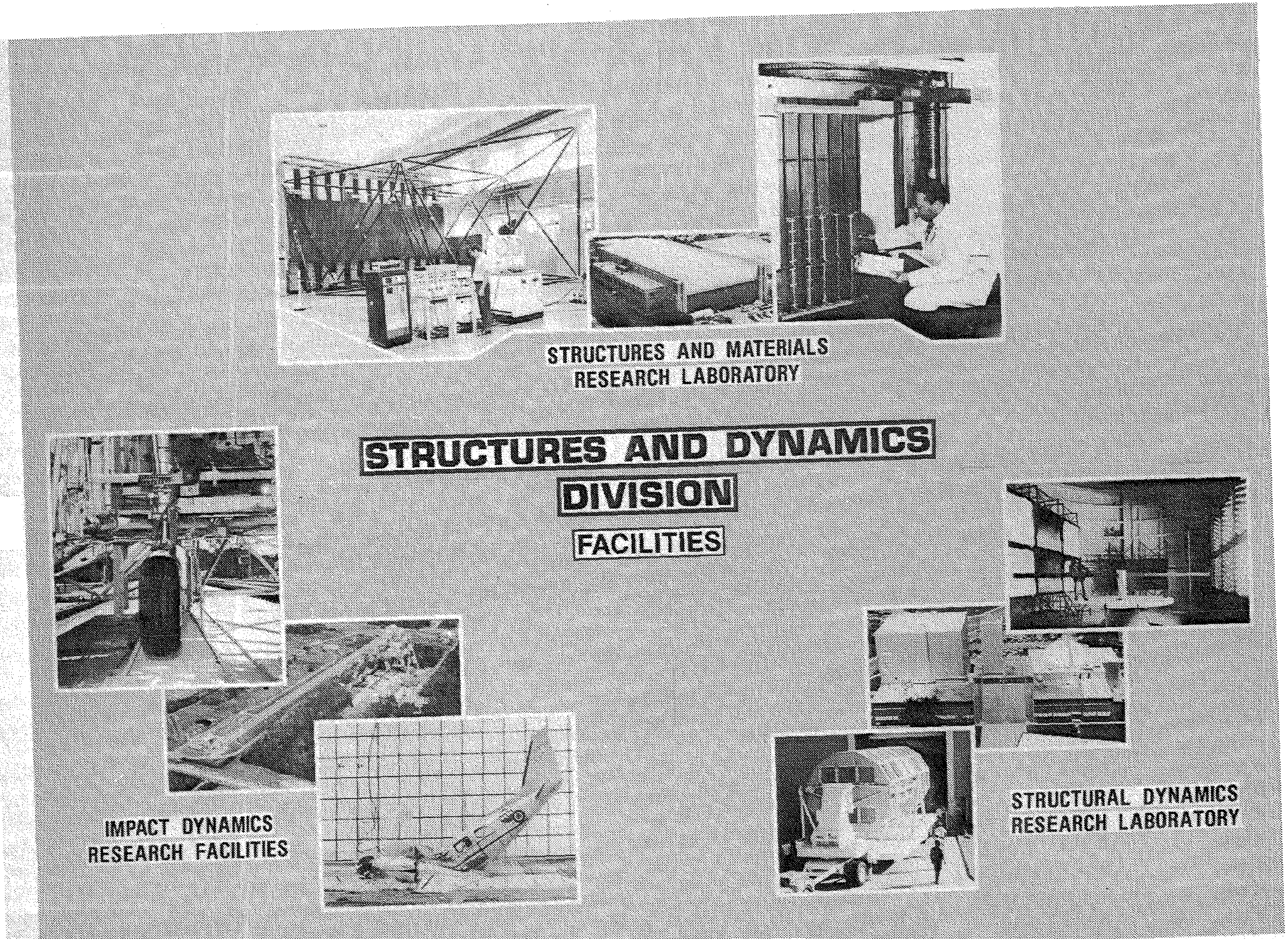
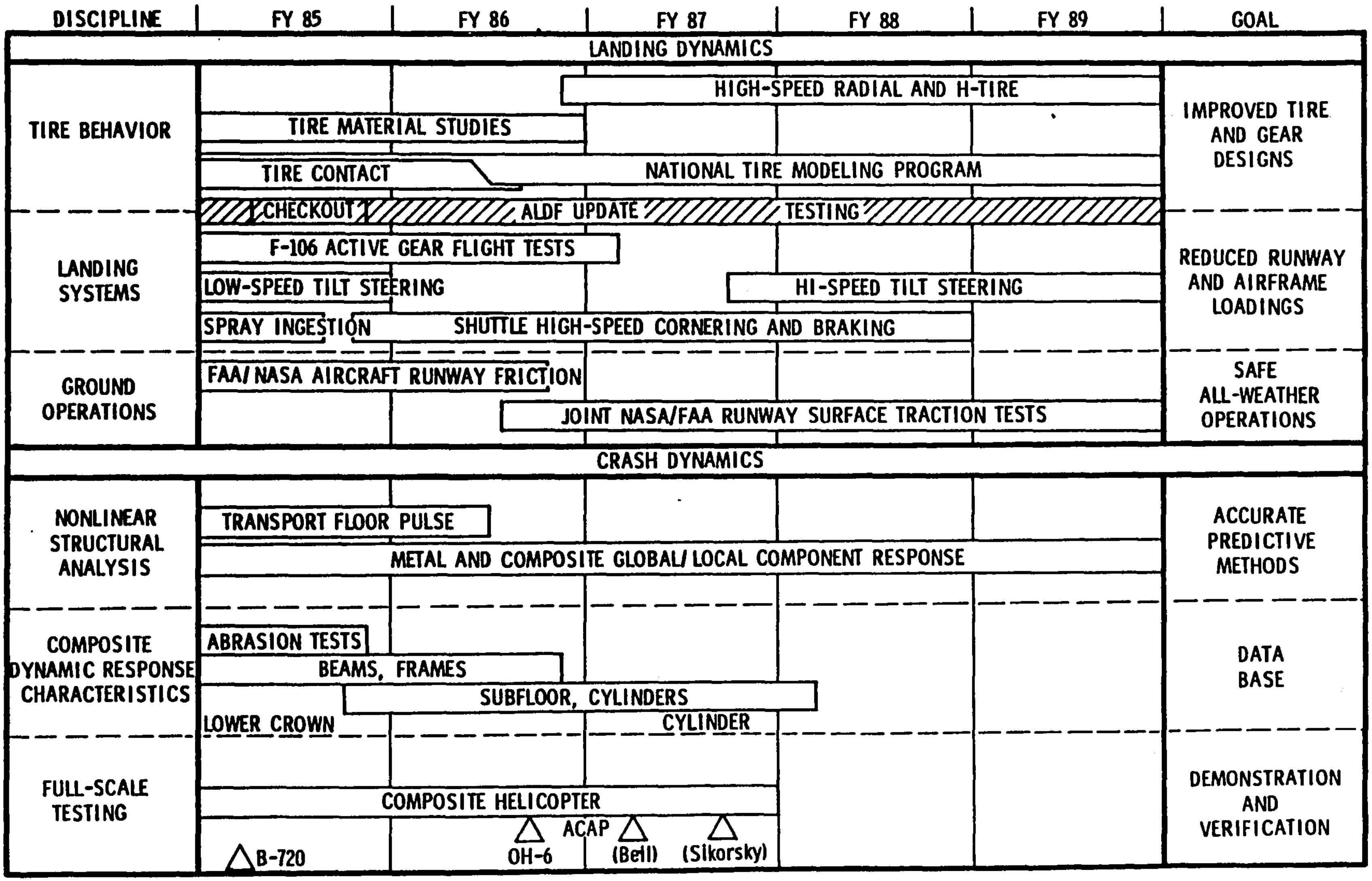

STRUCTURES AND MATERIALS
RESEARCH LABORATORY
STRUCTURES AND DYNAMICS
DIVISION
FACILITIES
IMPACT DYNAMICS
RESEARCH FACILITIES
STRUCTURAL DYNAMICS
RESEARCH LABORATORY

Figure 3.

III IMPACT DYNAMICS BRANCH

IMPACT DYNAMICS BRANCH



III IMPACT DYNAMICS BRANCH

RTR 505-63-41-01 Composite Crash Dynamics

OBJECTIVE:

Establish a data base, develop a better understanding of the behavior, and generate or verify analytical and empirical tools to predict global response characteristics of composite structures under crash loading conditions.

FY 1986 PLANS:

- o Prepare energy absorbing transport seat for airbus fuselage drop test
- o Complete analysis and tests of impact behavior of composite ring frames
- o Prepare composite subfloor sections for drop tests
- o Initiate composite energy absorbing helicopter-GA subfloor component testing
- o Initiate testing and analysis of scale model composite beams subjected to impact loads
- o Make preparations for full-scale crash test of ACAP helicopter

APPROACH:

In FY 1986 the main focus will be conducting static and dynamic combined bending and axial loading tests on representative helicopter and scaled transport composite components. Develop in-house test methods, procedures and apparatus to conduct static and dynamic combined bending and axial loading tests on representative scaled composite components. Develop a data base to evaluate the effect of combined bending and axial loads on global response, stiffness and failure, and residual strength after failure. Analytical predictions using existing modified nonlinear computer programs and newly developed analysis methods will be compared to the experimental results. Supportive contractual efforts will be used mainly to fabricate composite components requiring special tooling.

MILESTONES:

- o Perform parametric study of transport crash scenarios using updated finite element model, October 1985
- o Conduct water impact tests on generic metal helicopter subfloors, October 1985

- Initiate procurement of composite filament-wound stiffened cylinder (Lockheed-California), November 1985

- Conduct drop test on composite subfloor skeleton and compare with DYCAST predictions, April 1986

- Conduct drop test on transport composite crown section (Lockheed ACEE contract), February 1986

- Conduct joint full-scale crash demonstration of all-composite helicopter airframe (OH-6) with U.S. Army and Hughes Helicopter Co., September 1986

FY 1985 ACCOMPLISHMENTS:

- Obtained structural crash impact data on a controlled impact demonstration of a full-scale transport

- Completed runway abrasion tests of coupons, beams and stiffened panels

- Conducted tests and performed DYCAST analysis of metal and composite fuselage frames

- Contractually obtained three composite subfloor skeleton specimens

- Completed testing and analysis of composite beams under combined axial-bending impact loadings (VPI&SU grant)

- Completed study of nonlinear response and failure characteristics of internally pressurized composite cylindrical panels

RTR 505-63-41-02 Aircraft Landing Dynamics

OBJECTIVE:

Advance the technology for safe, economical all-weather aircraft ground operations including the development of new landing gear systems.

FY 1986 PLANS:

- National Tire Modeling Program

  - Continue development of family of tire analysis codes
  - Add to tire material property data base
  - Initiate rolling contact force measurements

- Aircraft Landing Dynamics Facility (ALDF)

  - Complete testing of Shuttle main gear tire

- Check out second carriage operation
- Initiate radial and H-type tire program

o Complete joint NASA/FAA Runway Surface Friction Program

APPROACH:

In FY 1986 the main focus will be developing high-speed tire frictional and mechanical property data base in support of Industry and Shuttle landing operations. Coordinate in-house research, grants, and contracts with U. S. tire industry experimental effort to carry out National Tire Modeling Program. Conduct detailed studies of forces and moments in tire footprint for comparison with analytical tire predictions. Develop tire contact algorithms to include friction and rolling effects in support of National Tire Modeling Program and install these algorithms on the Computational Structural Mechanics software test bed. Develop experimental methods for measuring material properties of tire constituents. Conduct spinup, high-speed cornering, and braking tests in support of the Space Shuttle Orbiter. Obtain frictional and mechanical property data on type H and radial ply aircraft tires.

MILESTONES:

o Tire/contact studies integrated into CSM activity, October 1985

o Publish report of exploiting symmetrics in tire modeling, October 1985

o Present paper on Aircraft Landing Dynamics Facility at SAE AeroTech 85 Meeting, October 1985

o Present paper on tilt steering at SAE AeroTech 85 meeting, October 1985

o Conduct tests on type H and radial ply aircraft tire, March 1986

o Publish results from tests supporting Shuttle, June 1985

o Publish initial paper on radial tire friction characteristics, September 1986

FY 1985 ACCOMPLISHMENTS:

o Aircraft Landing Dynamics Facility operational in July

o Tire modeling sessions at GWU/NASA Symposium and at Tire Society meeting focus on National Tire Modeling Program needs

o Spray ingestion tests completed on general aviation and DC9 (bias and radial) nose gear tires

- o NASA/FAA snow and ice airplane tests completed

- o Identified and measured nose wheel side forces due to tilt steering

- o Modified shuttle simulator software to include tilt steering phenomena

- o Tire footprint force paper presented at ASTM Symposium on Tire/Pavement Interface, June 1985

RTR 505-63-41-03 Flight Test of F106B Active Control Landing Gears

OBJECTIVE:

Demonstrate the load alleviation characteristics of active control landing gears by flight tests.

FY 1986 Plans:

- o Prepare F106B for flight demonstration of active control gears

APPROACH:

In FY 1986 the main focus will be preparing the F-106B for flight demonstration of active control gears. Acquire and modify a set of F106B landing gear for active controls using concepts developed under RTR 505-63-41-02 (Aircraft Landing Dynamics). Conduct drop tests of modified active gear using the landing dynamics facility and deliver test-ready gear to the hangar for installation and flight tests on NASA F106B aircraft at Wallops Flight Facility. Flight tests include touchdown and taxiing over various runway surfaces with and without active control operation.

MILESTONES:

- o Main and nose gear modified for active control, September 1985

- o Complete static drop tests of modified main and nose gear, January 1986

- o Initiate flight tests, October 1986

- o Complete flight tests, December 1986

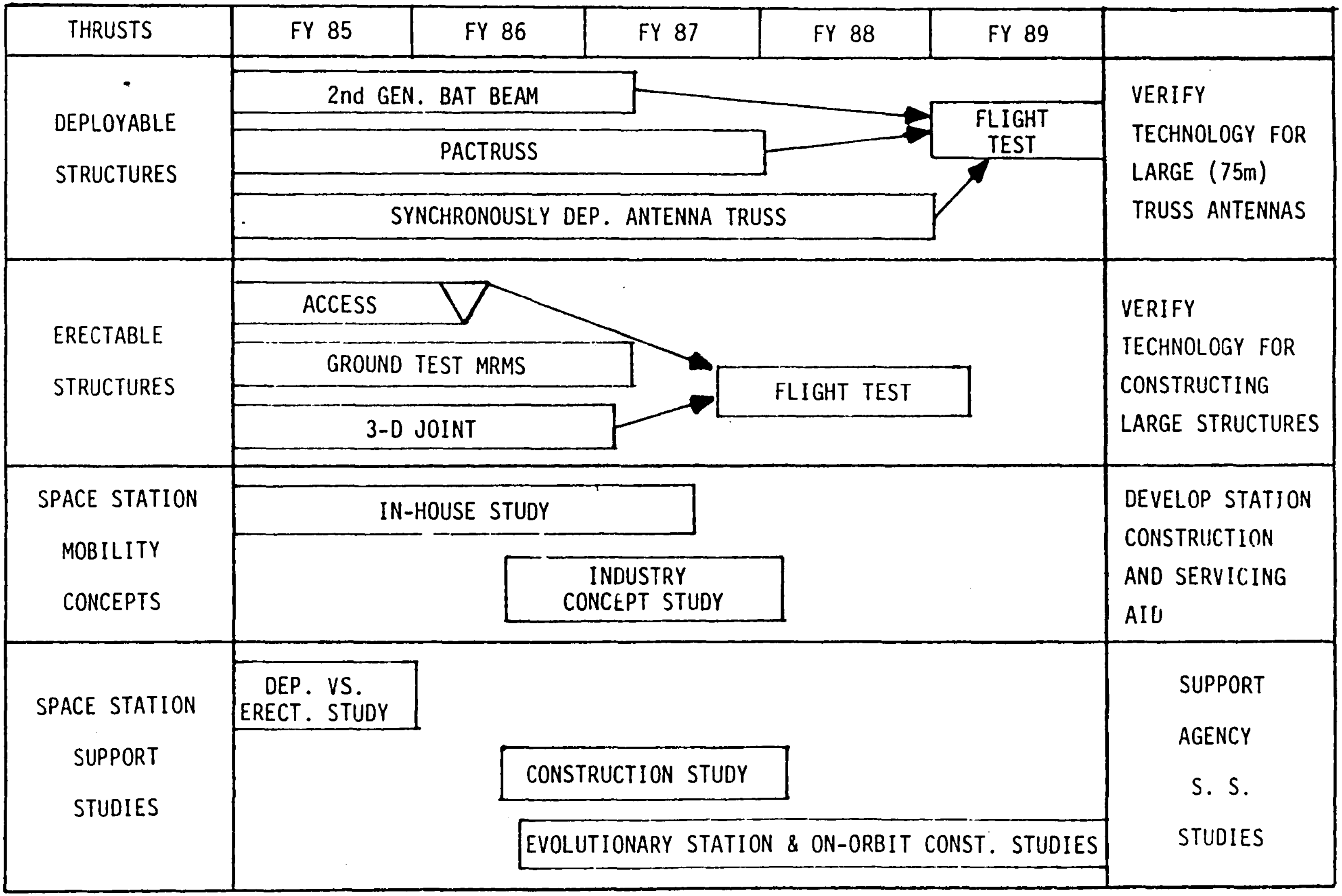
FY 1985 ACCOMPLISHMENTS:

- o Gear modification and controller designs completed

- Preliminary ASRB review held
- Drop test fixture designs completed, fabrication started

IV STRUCTURAL CONCEPTS BRANCH

ADVANCED SPACE STRUCTURES



IV STRUCTURAL CONCEPTS BRANCH

RTR 506-43-41-02 Advanced Space Structures Concepts

OBJECTIVE:

Develop deployable and erectable structural concepts and associated design technology for antenna and reflector structures and space station.

FY 1986 PLANS:

- o Design and fabricate synchronously deployable truss test article for 75M class antenna
- o Conduct ACCESS flight test
- o Complete ground test MRMS and initiate testing
- o Design, fabricate and test 2nd generation erectable joint

APPROACH:

In FY 1986 a major milestone will be the completion of the ACCESS on-orbit flight test and a major research thrust will be the fabrication and test of a 1-g mobile remote manipulator system and associated erectable hardware. Additional activities will be to procur and develop CAD capability for large space structures; develop scenarios for construction of large antennas and reflectors; fabricate deployable truss model and support MAST and space station scale model effort.

MILESTONES:

- o Conduct ACCESS flight test, December 1985
- o Fabricate ground test MRMS, April 1986
- o Procure CAD system, April 1986
- o 1-g test of MRMS, June 1986
- o Fabricate deployable truss module, June 1986

FY 1985 ACCOMPLISHMENTS:

- o Conducted ACCESS preflight tests
- o Conceived and fabricated model of a double-fold deployable truss (PACTRUSS)
- o Conceived a new low-cost, linear, erectable joint

- o Conceived a new 3-D growth capability erectable nodal cluster

RTR 481-32-13-01 MRMS (Mobile Remote Manipulator System)

OBJECTIVE:

Develop first generation design requirements and design drivers for an MRMS capable of operating on the space station. This study will investigate such items as the effects of flexibility, thermal distortions, and fabrication tolerance on mechanical operation of the MRMS, as well as understanding the design implications of operating on a large controlled structure such as the space station.

FY 1986 PLANS:

- o Conduct MRMS concept study

APPROACH:

In FY 1986 the main focus will be to determine design requirements and constraints for a mobile remote manipulator system for operation on the IOC space station. Specifically, point designs will be made of several MRMS's capable of operating on the space station truss structure. Trade studies of the design drivers will be conducted to determine system sensitivity to various parameters with an emphasis on station evolution. A report will be published on the second generation design requirements developed in the studies as well as on the identified potentially important design drivers and system discriminators.

MILESTONES:

- o MRMS concept study, November 1986

- o MRMS prototype design RFP, November 1986

FY 1985 ACCOMPLISHMENTS

- o Preliminary baseline MRMS concept has been conceived and a partial listing of design constraints and requirements has been prepared

RTR 481-32-23-01 PACTRUSS (Packageable Truss)

OBJECTIVE:

Conduct an on-orbit assembly study of space station constructed from a 15-ft. deployable double fold truss, and to design and fabricate a full-scale test article.

FY 1986 PLANS:

- o Conduct PACTRUSS deployment analysis

APPROACH:

In FY 1986 the main focus will be the design and fabrication of a full-scale deployable PACTRUSS. Specifically, we will explore various on-orbit assembly scenarios for space station considering the peculiar features offered by the 15-ft. deployable PACTRUSS, and after selecting a preferred scenario, design and fabricate a full-scale multiple bay beam section keel to evaluate its performance.

MILESTONES:

- o On-orbit assembly scenario for 15-ft. deployable PACTRUSS, December 1985
- o Design of full-scale beam, March 1986
- o Fabrication of multiple bay beam, September 1986

FY 1985 ACCOMPLISHMENTS:

- o A three-bay subscale model of the double-fold PACTRUSS has been fabricated and tested

RTR 481-32-23-02 Space Station Erectable Structures

OBJECTIVE:

Develop and evaluate candidate joints and graphite/epoxy struts to determine their suitability for use as the space station primary structure and to build a multi-bay component for use in structural tests.

FY 1986 PLANS:

- o Develop techniques for fabrication of struts and joints

APPROACH:

In FY 1986 the main focus will be the development of techniques for fabrication of high-stiffness graphite/epoxy struts and joints for space station structural framework. Specifically, plans are to conduct an extensive concept study of various techniques for fabricating high stiffness, tough, graphite/epoxy struts; develop fabrication process for selected strut and fabricate strut for multiple bay beam; conduct concept study of various low cost, linear 3-D erectable joints and characterize deformation characteristics of selected joint and fabricate joints for multiple bay beam.

MILESTONES:

- o Composite struts study task initiated, April 1986
- o Distortion analysis task initiated, April 1986

FY 1985 ACCOMPLISHMENTS:

- o New RTR

RTR 482-53-43-21 Erectable Structures

OBJECTIVE:

Develop and evaluate candidate joints and graphite/epoxy struts to determine their suitability for use as the space station primary structure and to build a multi-bay component for use in assembly tests and in testing an MRMS.

FY 1986 PLANS:

- o Conduct space station construction study

APPROACH:

In FY 1986 the main focus will be the development of techniques for fabrication of high-stiffness graphite/epoxy struts and joints for space station structural framework. Specifically, plans are to conduct an extensive concept study of various techniques for fabricating high stiffness, tough, graphite/epoxy struts; develop fabrication process for selected strut and fabricate strut for multiple bay beam; conduct concept study of various low cost, linear 3-D erectable joints and characterize deformation characteristics of selected joint and fabricate joints for multiple bay beam.

MILESTONES:

- o Demonstration of high stiffness, tough struts, October 1985
- o Strut fabrication process, October 1985
- o Characterized erectable joint, October 1985
- o Joints for multiple bay beam, August 1986

FY 1985 ACCOMPLISHMENTS:

- o Initial theoretical studies of preferred laminates have been completed and several fabrication techniques are under investigation

RTR 906-55-62-01 Truss Space Flight Test Definition

OBJECTIVE:

Define a Space Shuttle flight test of a truss structure to advance the technology of the construction of large space structures.

FY 1986 PLANS:

- o Advocate next construction flight experiment

APPROACH:

An in-house and contractual study will be conducted to establish technical goals and identify necessary elements of the flight test. The baseline 5-meter erectabls space station truss will be used as the focus of this study. The study will define the beam length, construction approach, structural test objectives, as well as ancillary testing that could be accomplished.

MILESTONES:

- o Initiate task contractual study, March 1986
- o First progress report from study, April 1986
- o Complete study, June 1986

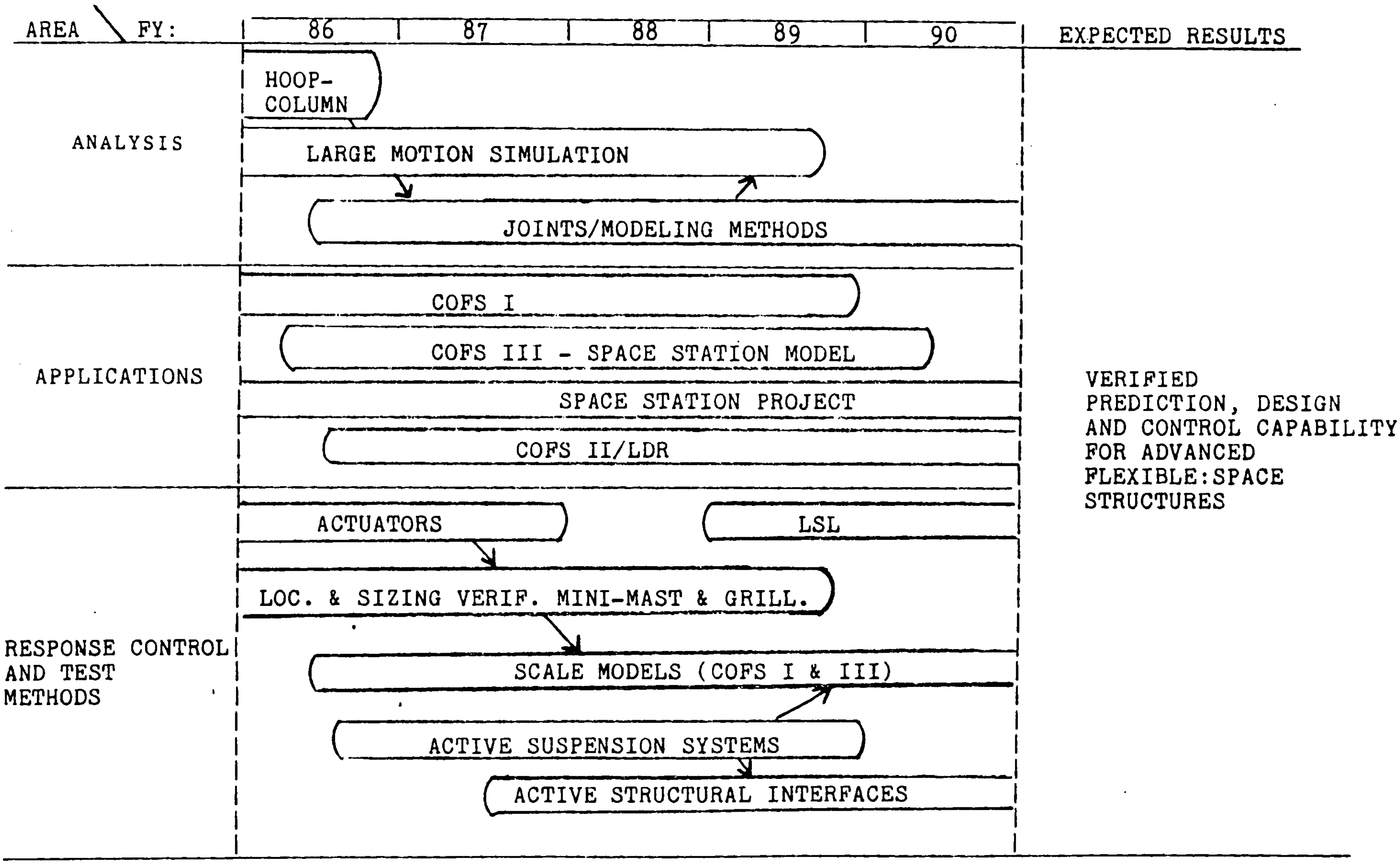
FY 1985 ACCOMPLISHMENTS:

- o New RTR

V STRUCTURAL DYNAMICS BRANCH

STRUCTURAL DYNAMICS BRANCH

ACTIVITIES



V STRUCTURAL DYNAMICS BRANCH

RTR 506-43-51-01 Vibration Control

OBJECTIVE:

Accomplish validated capability for on-line structural parameter identification and active and passive vibration attenuation for large flexible space structures.

FY 1986 PLANS:

- o Evaluate aerodynamic effects in slewing control experiments

APPROACH:

In FY 1986 the main focus will be experimental verification of previously developed control techniques. Active and passive control techniques for reducing the response of low-frequency flexible structures will be verified using a large joint-dominated truss-beam as a focus. A coordinated analysis and test program will be conducted at both element and system levels. Physical elements such as joints, actuators, and electronic components which provide mathematically-defined optimal performance will be built and analyzed individually and as parts of systems. Laboratory tests of hardware components on laboratory models will be conducted to verify and improve analyses. Test methods which satisfactorily compensate for gravity effects on low-frequency structures will be verified.

MILESTONES:

- o Initiate in-house development of telescoping member actuator with closed-loop electronics, December 1985

- o Initiate multiple actuator communications concepts, March 1986

FY 1985 ACCOMPLISHMENTS:

- o Analysis method for optimum member damper sizing developed

- o Large-angle optimal slewing of flexible panel demonstrated

- o Eigenvalue realization algorithm documentation draft completed

- o Optimal design approach developed for flexible structure control which includes actuator dynamics effects

RTR 506-43-51-02 Advanced Spacecraft Dynamics Analysis

OBJECTIVE:

Develop and validate analytical methods for predicting the coupled structural dynamics and control of multi-body space space structures with flexible components, interfaces, dissipative mechanisms and large amplitude responses.

FY 1986 PLANS:

- Begin LATDYN 3-D program development

APPROACH:

In FY 1986 the main focus will be the initiation of a three-dimensional computerized simulation of controlled dynamics of multibody flexible space structures as encountered in deployment and slewing. Included in this thrust is the development of improved modularized transient algorithms for concurrent computing, and realistic verified models for joint and interface damping mechanisms.

MILESTONES:

- Complete multi-body synthesis of generic space station model, December 1985
- Initiate 3-D LATDYN coding, December 1985
- Document nonlinear joint characterization and response, December 1985
- Install substructuring capability in BUNVIS, January 1986
- Incorporate controls and berthing capability into 2-D LATDYN, February 1986
- Incorporate structural joint models into LATDYN, March 1986
- Identify transient algorithms applicable to concurrent processing, September 1986

FY 1985 ACCOMPLISHMENTS:

- Space station generic model tests nearly complete
- LATDYN applied successfully to deployment of space station keel
- Nonlinear modeling requirements for large angle maneuver identified
- Verified joint models incorporated into finite element program

- o Theory for tapered members incorporated into BUNVIS

- o Improved convergence method reduced BUNVIS computational time by 50 percent

RTR 506-43-51-03 Dynamics of 15M Hoop-Column Antenna Structure

OBJECTIVE:

Develop verified structural dynamics test and analysis methods applicable to large cable-stiffened antenna structures.

FY 1986 PLANS:

- o Conduct dynamic tests on 15M hoop-column antenna

APPROACH:

In FY 1986 the main focus of this work is to conduct dynamic tests in the LaRC 16M Thermal Vacuum Chamber on a 15M diameter hoop column antenna structure constructed by the Harris Corp. State-of-the-art parameter identification methods will be used to determine the dynamic characteristics of the antenna. The experimental data base will be used to confirm advanced dynamic characteristics of the antenna. The experimental data base will be used to confirm advanced dynamic analysis models using finite elements and repeating element technology of the BUNVIS computer code. Simplifying analytical assumptions will be studied to reduce the computational effort.

MILESTONES:

- o Initiate modal vibration tests of 15M antenna, September 1985

- o Let contract for test and data analysis, October 1985

- o Let contract with Edighoffer, Inc., October 1985

- o Reduce test data and refine analysis models, January 1986

- o Apply advanced parameter identification algorithms, February 1986

- o Initiate documentation of test and analysis, July 1986

- o Complete tests, August 1986

FY 1985 ACCOMPLISHMENTS:

- o Completed preliminary finite element analysis

- o Conducted shape correction analysis and implemented results on antenna

- o Completed instrumentation and test fixture installation in 16M Thermal Vacuum Chamber

RTR 506-48-31-02 Beam Dynamics Ground Test

OBJECTIVE:

Validate ground test technology and conduct tests necessary to demonstrate flight readiness for the Mast experiment.

FY 1986 PLANS:

- o Test COFS-1 20M prototype and components

APPROACH:

In FY 1986 the main focus is the experimental and analytical characterization of a 20M truss beam (mini-Mast). The mini-Mast program will define the appropriate tests to model joints as individual elements and analytical methods of including joint characteristics in a global dynamics model will be evaluated. Global dynamic characteristics of the mini-Mast will be measured using state-of-the-art techniques and compared to analytical results. Test methods and suspensions applicable to the 60M mast flight article will be studied and facility preparation for the 60M test will begin.

MILESTONES:

- o Initiate support fixture fabrication for mini-Mast, October 1985
- o Initiate joint characterization tests, January 1986
- o Initiate modal test on 20M mini-Mast, March 1986
- o Demonstrate member actuator concept, June 1986

FY 1985 ACCOMPLISHMENTS:

- o Contract for mini-Mast construction awarded to Astro Research Corp.
- o Preliminary analytical models developed

RTR 546-01-31-01 COFS III Technology

OBJECTIVE:

Develop structural dynamics technology for COFS ground and flight experiments.

FY 1986 PLANS:

- o Test full-scale and 1/4-scale space station truss beams

APPROACH:

In FY 1986 the main focus will be on developmentof the COFS III ground experiment model which will be space station oriented in anticipation of on-orbit flight data from the future station. Analysis and test methods for the dynamics and control of multiple-component, joint-dominated structures will be emphasized. Desired model characteristics and fabrication requirements will be developed and test procedures which minimize gravity effects will be studied. In related technology, the scaling of friction in structural joints will be studied and structural members which function as dynamic actuators will be developed. Design analyses of the COFS I and II models will be conducted to optimize flight data return.

MILESTONES:

- o Initiate study of joint scaling/analysis, October 1985
- o Issue RFP for COFS III model, January 1986
- o Initiate contract for member actuator, March 1986
- o Award model development contract, September 1986

FY 1985 PROGRESS:

- o Preliminary study contract initiated

RTR 482-53-53-34 Space Station Structural Dynamics

OBJECTIVE:

Develop, early in the space station program, verified analytical capability required for space station construction, maneuvers, berthing and robotic arm manipulation.

FY 1986 PLANS:

- o Begin LATDYN 3-D program development

APPROACH:

In FY 1986 the main focus will be the incorporation of new technology analytical methods into usable computer programs which can aid the space station project in systems engineering and integration. Emphasis is on a convected coordinate approach for treating connected flexible components.

MILESTONES:

- o Document 2-D LATDYN theory, December 1985
- o Complete 2-D LATDYN enhancements for berthing and controls, April 1986

FY 1985 ACCOMPLISHMENTS:

- o IOC keel deployment risk assessed for erectable versus deployable study
- o User friendly enhancements to LATDYN installed
- o 2-D LATDYN transfer to JSC on VAX
- o Space station reference configuration dynamics documented in TM

RTR 482-53-53-38 Space Station Model Definition/Design

OBJECTIVE:

Develop a sub-scale replica model of the space station and a program for its use in dynamic development and qualification.

FY 1986 PLANS:

- o Begin space station model definition

APPROACH:

In FY 1986 the main focus will be on procedures for use of a replica model in space station development. A replica model of the space station will be designed and constructed at approximately one-fourth to four-tenths scale for use in predicting space station on-orbit dynamics. Initial efforts will be on development and tests of an IOC configuration in time to assist space station CDR. Scar effects on the IOC configuration resulting from advanced configurations also would be determined.

MILESTONES:

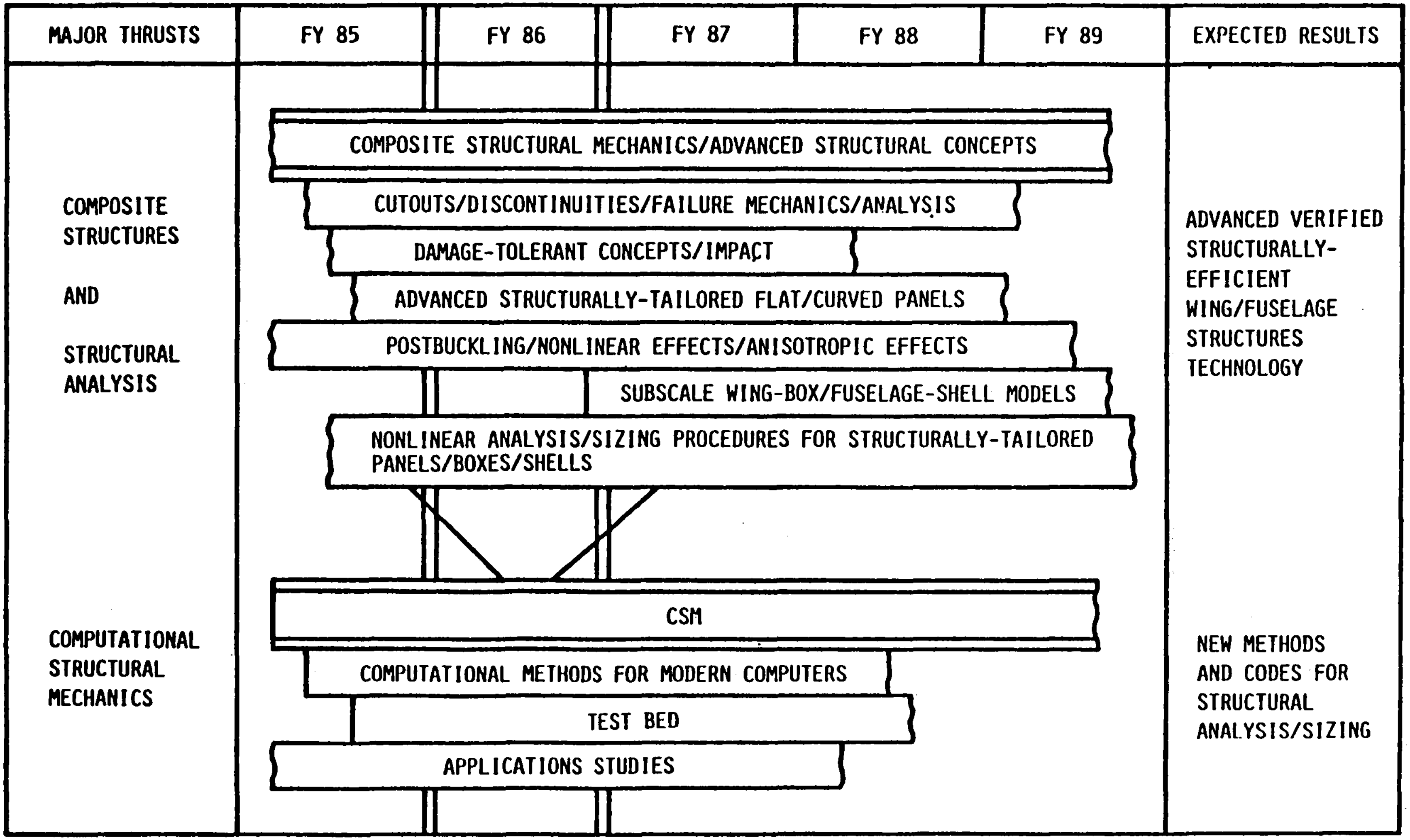
- o Initiate design/definition contract for a replica model, March 1986

FY 1985 ACCOMPLISHMENTS:

- o Model feasibility study under way

VI STRUCTURAL MECHANICS BRANCH

STRUCTURAL MECHANICS



VI STRUCTURAL MECHANICS BRANCH

RTR 505-63-11-03 Composites Structural Mechanics

OBJECTIVE:

Develop mechanics technology required for the verified design of efficient, fault-tolerant advanced-composite aircraft structural components subject to combined loads, impact, postbuckling effects and local discontinuities.

FY 1986 PLANS:

- o Develop and evaluate new structurally-efficient composite panel concepts

- o Develop models of failure mechanisms of advanced composite structural components subjected to compression and bending

APPROACH:

In FY 1986 the main focus is on verifying an analysis for the stiffener pull-off problem and on development of a stiffener crippling analysis method for composite stiffeners. Structural mechanics issues of advanced structural concepts and configurations that exploit the advantages of composites will be studied analytically and experimentally. Compression, tension, shear and combined loads representative of aircraft primary wing and fuselage components will be considered. Methods will be developed for predicting strength, buckling and stiffness of composite components including the effects of foreign-object damage, cutouts and postbuckling. Failure mechanisms will be identified and analytical models for predicting failure will be developed. Test results will contribute to an experimental data base for composite airframe structural components including damage, cutouts and postbuckling and will be correlated with analytical predictions.

MILESTONES:

- o Initiate study of postbuckling behavior of thermoplastic stiffened panels, November 1985

- o Complete study of effect of load transfer on composite panel performance, May 1986

- o Verify skin-stiffener interface failure analysis and establish realistic failure criterion for skin-stiffener failure mode for postbuckled stiffened panels, June 1986

- o Complete preliminary study of postbuckling strength of unstiffened and stiffened shear webs with cutouts, July 1986

- o Conduct analyses of composite plates with thickness discontinuities and correlate with experimental results, July 1986
- o Develop stiffener crippling analysis for composite stiffeners, September 1986

FY 1985 ACCOMPLISHMENTS:

- o Completed combined shear/compression interaction tests for stiffened composite panels with postbuckling behavior
- o Criterion developed for determining when anisotropic effects are important for the buckling of composite panels
- o Preliminary tests on pressure-loaded stiffened panels indicate that stiffener bending stiffness and flange stiffness can influence local bending gradients in panel skins
- o Identified interlaminar failure modes of unstiffened shear webs loaded into the postbuckling range and correlated test and analysis results for postbuckling behavior
- o Completed preliminary study of curved composite stiffened compression panels loaded into the postbuckling range. Curvature increases buckling and failure loads. Response predicted accurately when geometric imperfections are included in the analysis

RTR 534-06-23-08 Advanced Composites Structural Concepts

OBJECTIVE:

Develop composite structural concepts and design technology needed to realize the improved performance, structural efficiency, and lower-cost advantage offered by new materials systems and manufacturing methods for advanced aircraft structures.

FY 1986 PLANS:

- o Conduct damage tolerance and open hole tests on advanced structural concepts with and without adhesive interleaving
- o Conduct anisotropic tailoring study of a high-aspect-ratio wing model

APPROACH:

In FY 1986 the main focus is to evaluate the structural performance and damage tolerance characteristics of potentially low-cost filament wound and pultruded structural concepts. Innovative structural configurations for advanced transport applications will be developed and evaluated for improved performance, structural

efficiency, and damage tolerance. Interdisciplinary constraints including those imposed by aeroelastic tailoring, laminar flow, acoustics, crash dynamics, and control will be included in the design of new structural concepts and their effects will be evaluated. Associated structural mechanics issues peculiar to these new design concepts will be studied and selected concepts will be evaluated experimentally.

MILESTONES:

- o Initiate study task for innovative low-cost filament wound wing structure, October 1985
- o Conduct damage tolerance and open hole tests on filament wound laminates with/without interleaving, November 1985
- o Initiate anisotropic tailoring study of laminar flow transport wing, November 1985
- o Design and test TEM hat-stiffened panel, December 1985
- o Conduct postbuckling experiments on anisotropic filament wound plates and compare with analysis, December 1985
- o Conduct test evaluation of pultruded stiffeners and panel, January 1986
- o Design and fabricate geodesic filament wound panels, May 1986

RTR 505-63-31-01 Structural Mechanics Analysis

OBJECTIVE:

Develop structural analysis and sizing methods for predicting and designing for the nonlinear behavior of aerospace structures including postbuckling phenomena and ultimate strength.

FY 1986 PLANS:

- o Extend stiffness tailoring studies to stiffened plates with holes
- o Develop nonlinear modal interaction analysis for plates

APPROACH:

In FY 1986 emphasis is on implementing into STAGS an in-house-developed nonlinear modal interaction analysis that allows mode changes in postbuckling analyses of built-up components and on developing structural tailoring procedures for composite structures. Advanced structural analysis and sizing procedures for aerospace structures with nonlinear responses will be developed. Procedures that account for large deflections and rotations will

be developed for analyzing flat and curved composite stiffened structural components. Procedures also will be developed for detailed 3-D stress analysis of composite components. Results will be compared with failure criteria that predict ultimate strength. New failure analyses will be developed as needed.

MILESTONES:

- o Develop nonlinear modal interaction analysis for plates, March 1986
- o Initiate development of stiffness tailoring capability for stiffened plates with holes, March 1986
- o Initiate development of error analysis and correction method for plates with holes and nonlinear response, March 1986
- o Develop simultaneous analysis and sizing procedures for beams with multimode buckling behavior, April 1986
- o Implement nonlinear modal interaction analysis into STAGS for general purpose problems, September 1986

FY 1985 PROGRESS:

- o Developed accurate and efficient higher-order nonlinear transverse shear theory for composite plates and shells
- o Demonstrated that stiffness tailoring with a structural sizing capability can reduce weight and increase strength of compression-loaded composite plates with holes
- o Developed prototype computer program for carrying out structural optimization with constraints using nonlinear structural analysis
- o Documented implementation of in-house-developed equivalence transformations into STAGS code for improving efficiency of postbuckling calculations
- o Developed and documented corotational element capability in nonlinear STAGS code
- o Demonstrated effects of measured initial geometric imperfections on the analysis of stiffened composite compression panels loaded into the postbuckling range
- o Developed prototype sizing code for stiffened composite plates with damage constraints

COMPUTATIONAL STRUCTURAL MECHANICS

FIVE YEAR PLAN

MAJOR THRUSTS	FY 85	FY 86	FY 87	FY 88	FY 89	EXPECTED RESULTS
METHODS FOR MODERN COMPUTERS	LOCAL/GLOBAL, TRANSIENT DYNAMICS					ADVANCED ANALYSIS FORMULATIONS AND COMPUTATIONAL TECHNIQUES
		TIRE/CONTACT, THERMAL STRESSES				
			FAILURE ANALYSIS			
	PARALLEL PROCESSING					
TEST BED	NICE/SPAR ON VAX, FLEX, SUPERCOMPUTER					EVALUATE AND TRANSFER NEW METHODS
	IMPROVE EXECUTIVE, DATA MANAGER, MODULE INTERFACES					
	METHODS DEVELOPMENT AND APPLICATIONS STUDIES					REQUIREMENTS FOR ADVANCED SOFTWARE
APPLICATIONS STUDIES	COMPOSITE PANELS, COMPONENTS, SUBSCALE MODELS					CONFIRMS ANALYSIS STRENGTHS AND DEFICIENCIES
	SPACE STATION DYNAMICS, LARGE SPACE-ANTENNA					
			STRENGTH OF AEROSPACE STRUCT. UNDER STATIC AND DYNAMIC LOADS			SOLUTIONS TO DIFFICULT STRUCT. ANAL. PROBLEMS

RTR 505-63-31-02 Computational Structural Mechanics

OBJECTIVE:

Develop advanced structural analysis and computational methods that exploit advanced computer hardware, and develop standard generic software system for structural analysis.

FY 1986 PLANS:

- o Complete and document local/global stress analysis study
  - Stiffened composite panel with hole
- o Install and demonstrate NICE/SPAR on FLEX computer
  - Address focus benchmark problems
- o Develop concurrent sparse matrix utilities for NICE/SPAR
- o Evaluate error analysis techniques
  - Identify most promising approaches
- o Demonstrate substructuring capability on FLEX
- o Ship NICE/SPAR to COSMIC

APPROACH:

In FY 1986 emphasis will be on upgrading initial test bed (NICE/SPAR) and on developing analysis capability for a new LaRC multiprocessor computer. Methods research will emphasize procedures that exploit computers having multiple processors and a concurrent processing capability. To aid in the methods development research a test bed system will be created. It will consist initially of software for Langley's VAX and CYBER computers and a combination of software and hardware for concurrent processing. A standard generic software system that can accept applications modules will be developed. This software system will be aimed at the computers and aerospace structural analysis problems of the late 1980's and beyond.

MILESTONES:

- o Initiate task assignment contract for analysis test bed and methods research, December 1985
- o Assess error analysis techniques for finite element method, December 1985
- o Document study of local/global stress analysis for stiffened composite panel with discontinuous stiffener, April 1986
- o Define NICE/SPAR modules for methods research in nonlinear static and dynamics analysis, September 1986

- Develop and demonstrate a linear finite element code for a new LaRC multiprocessor computer, September 1986

FY 1985 ACCOMPLISHMENTS:

- Awarded contract to acquire NICE analysis test bed
- Developed, installed, and checked out initial NICE/SPAR test bed
- CSM analysis methods workshop held June 1985
- FLEX parallel processor computer contract awarded; computer delivered July 26, 1985
- Transient dynamics algorithm and inverse power eigenvalue solver demonstrated to be efficient on parallel processor computer
- Demonstrated material and geometrically nonlinear column collapse analysis on parallel processor computer
- Wrote definitive survey paper on solutions of partial differential equations on vector and parallel processor computers
- Developed compact finite element formulation of elasticity equations that reduced computer storage requirements
- Substantially upgraded VAX computer in Building 1229

VII ACCOMPLISHMENT HIGHLIGHTS

IMPACT DYNAMICS BRANCH

SHUTTLE ORBITER CORNERING FORCE PHENOMENON IDENTIFIED AND MEASURED

Sandy M. Stubbs
Impact Dynamics Branch
Extension 2796
November 1984
RTOP 505-45-14

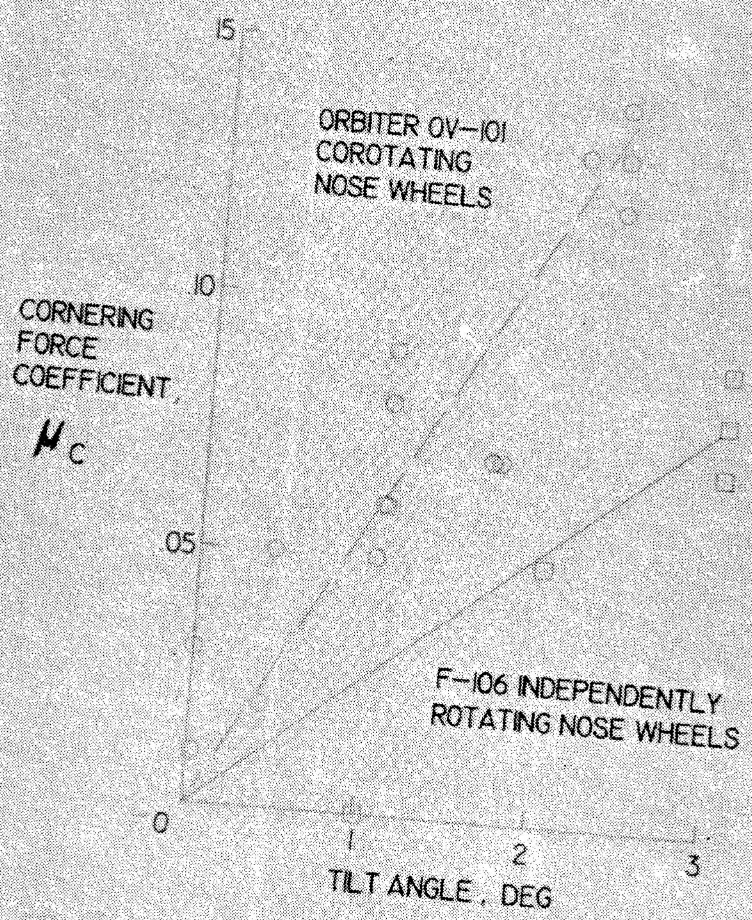
Crosswind landings of the Space Shuttle Orbiter have required a significant amount of differential braking above that which was predicted in computer simulators to maintain directional control on the runway. It was learned that in the presence of a crosswind force on the side of the orbiter,the down wind landing gear was loaded differentially enough compared to the upwind gear to produce a roll or tilt attitude of the vehicle. Research tests on a 1/11 scale model of an HL-10 vehicle back in 1965 indicated that a tricycle landing gear system would produce side forces even with a free castoring nose wheel if the vehicle was moving along the runway in a rolled or tilted attitude. Thus, it was necessary to determine the side forces on the orbiter for inclusion in landing simulators to study the tilt steering effects on handling problems and brake wear problems evidenced during crosswind landings.

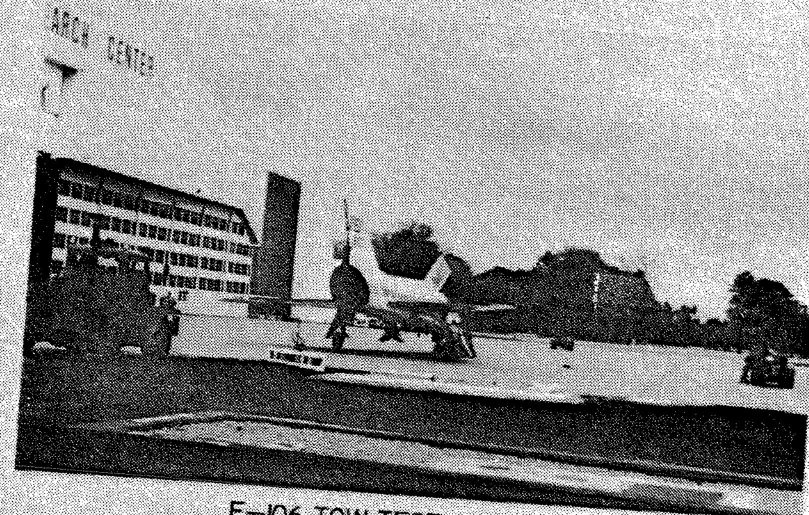
To determine the cornering forces on the orbiter due to this tilt steering phenomenon a towing technique was developed using an F-106 aircraft that had a twin nose tire configuration. The F-106 was used to demonstrate the equipment needed, the safety of the test, and the ease of conducting this type of test on the actual orbiter vehicle and to measure for the first time the magnitude of the cornering force due to tilt on a full size aircraft.

The photographs show the F-106 and the orbiter OV-101 and associated towing tugs, idler tugs and braking tugs. A triangle of cables connected the test vehicle, tow tug, and idler tug, and the idler tug was positioned to the right side of the nose wheel. The tow tug pulled both the test vehicle and the idler tug. A cable from the idler tug to the nose gear of the vehicle was instrumented to measure side force. The test vehicles were tilted away from the idler tug at angles up to 3 and 2 1/4 for the F-106 and orbiter respectively. The plot shows the cornering force coefficients for both the F-106 with independently rotating nose wheels and the orbiter with corotating nose wheels. Data from the orbiter tests have now been included in landing simulators to aid in the study of braking problems and nose wheel steering evaluations.

NASA
L-84-13,465

SHUTTLE ORBITER CORNERING FORCE PHENOMENON IDENTIFIED AND MEASURED





F-106 TOW TEST SETUP

SHUTTLE ORBITER OV-101 TOW TEST

GOVERNMENT/INDUSTRY CID WORKSHOP

Robert J. Hayduk
Impact Dynamics Branch, SDD
Extension 3795
May 17, 1985

(RTOP 505-45-11)

The Government/Industry CID Workshop was held at NASA Langley on April 10, 1985. The 74 participants were equally divided among industry and government agencies. Four foreign countries were represented - France, Germany, Britain, and Canada - with the largest contingent (seven) from France.

The overall objectives of the Workshop were as follows:

- preliminary release of structural loads data from CID;
- preliminary release of data on seats, dummies, restraint systems, galleys, bins, and flight data recorders; and
- interaction with the user community.

Speakers from NASA Langley, NASA Ames-Dryden, the FAA Technical Center, Naval Air Test Center, Simula, Inc., Kentron International, and System Development Corporation presented the CID plans, accomplishments, and preliminary data.

The Workshop information (six handouts plus presentations) was well received by the attendees. Perhaps the most significant information the attendees gained from the Workshop was an understanding of the importance of the analytical structural models, their correlation with the CID structural data, and future parametric studies.

A formal publication (CP) is planned in the near future to document the Workshop presentations, attendees, questions, and answers.

GOVERNMENT/INDUSTRY CID WORKSHOP

- DATE: APRIL 10, 1985
- PLACE: LANGLEY RESEARCH CENTER
- ATTENDANCE: 74 FROM GOVERNMENT AND INDUSTRY (INCLUDING FRANCE, GERMANY, BRITAIN, CANADA)
- PRELIMINARY RELEASE:
  - STRUCTURAL LOADS DATA
  - DATA ON SEATS, DUMMIES, RESTRAINT SYSTEMS, GALLEYS, BINS, FLIGHT RECORDERS
- INTERACTION WITH USER COMMUNITY
- SPEAKERS FROM LANGLEY, AMES-DRYDEN, FAATC, NAVAL AIR TEST CENTER, SIMULA, KENTRON, SDC
- SIX HANDOUTS PER ATTENDEE
- CP WILL BE PUBLISHED SUMMER 1985 TO INCLUDE PRESENTATIONS, ATTENDEES, QUESTIONS AND ANSWERS

AIRCRAFT LANDING DYNAMICS FACILITY

Sandy Stubbs and Granville Webb
Impact Dynamics Branch
May 24, 1985

(RTOP 505-45-14)

Research Objective

The objective of the current activity is the high speed checkout of the modified Aircraft Landing Dynamics Facility (ALDF). The ALDF consists of four major subsystems: 1) high pressure air and water storage system (L-vessel), 2) high speed valve, 3) carriage and 4) arresting system. The L-vessel and carriage can be seen in the above photo but the valve is obscured with water and the arresting system is 2200 feet down the track. The design requirement is to launch at a pressure of 3150 psi resulting in a velocity of 220 knots (253 mph) which will double the maximum velocity of 110 knots (127 mph) for the old facility.

Approach

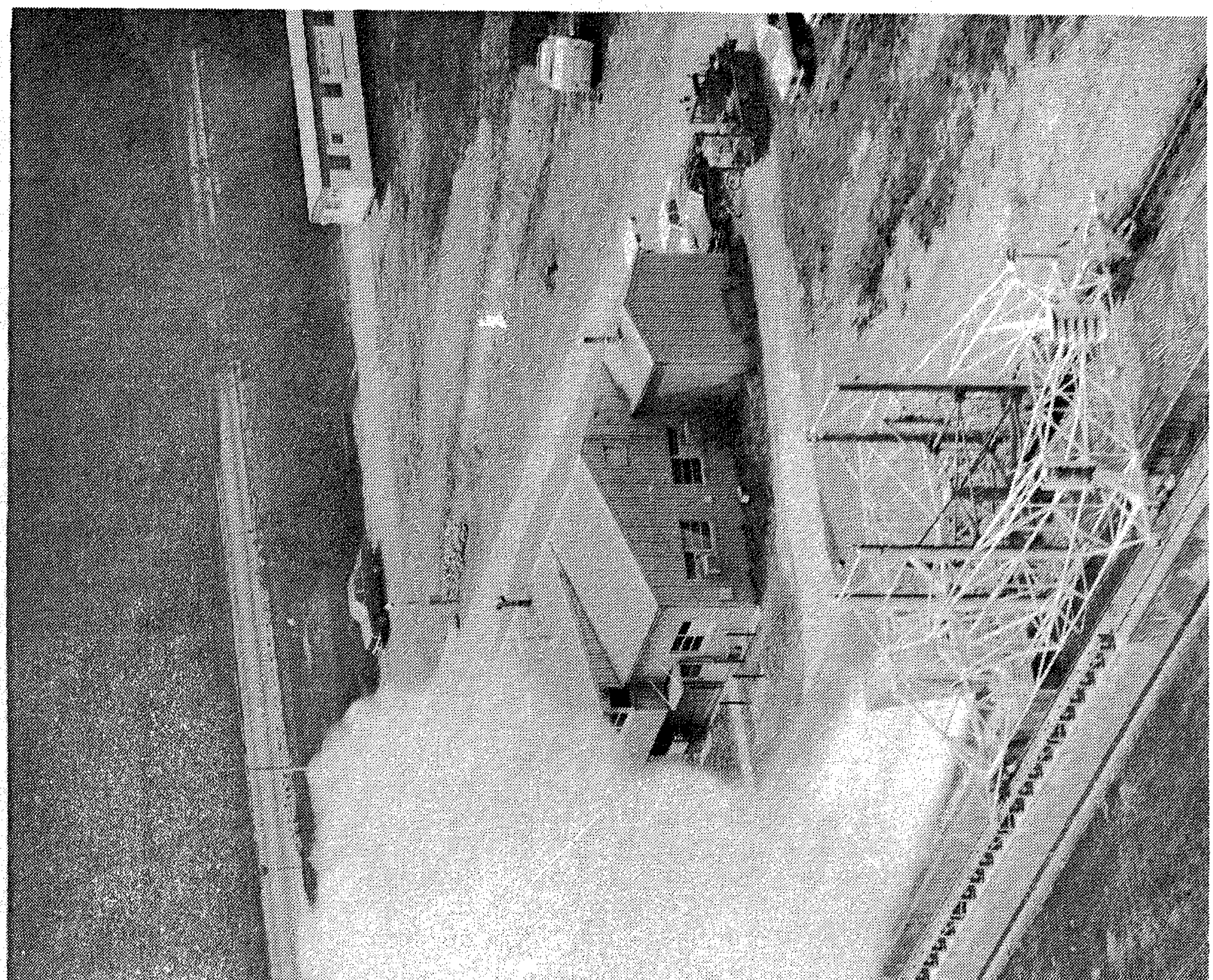
The four subsystems are instrumented with pressure gages, accelerometers, and strain gages to determine the loads and stresses being applied during the checkout of the facility to determine its performance characteristics. The checkout sequence will progress from low pressure catapults to high pressure catapults in pressure increments that are considered safe for the system operation.

Accomplishment Description

A total of 43 catapults have been completed at pressures up to 1750 psi, resulting in a maximum velocity of 167 knots (192 mph). The high speed valve, L-vessel, and the arresting system are performing as expected. However, the checkout program has identified higher than expected uplift forces on the carriage during the initial opening of the high speed valve, resulting in unacceptable stresses on the carriage.

Future Plans

The bucket area of the carriage is being strengthened and additional holddown capability is being incorporated in the catapult area. These modifications will be completed in May and the checkout program will be resumed in June with an expected completion by the end of June 1985.



NASA
L-85-5341

UPGRADED AIRCRAFT LANDING DYNAMICS FACILITY (ALDF) ACHIEVES DESIGN SPEED OF 220 KNOTS

Sandy M. Stubbs
Impact Dynamics Branch, SDD
Extension 2796
July 15, 1985

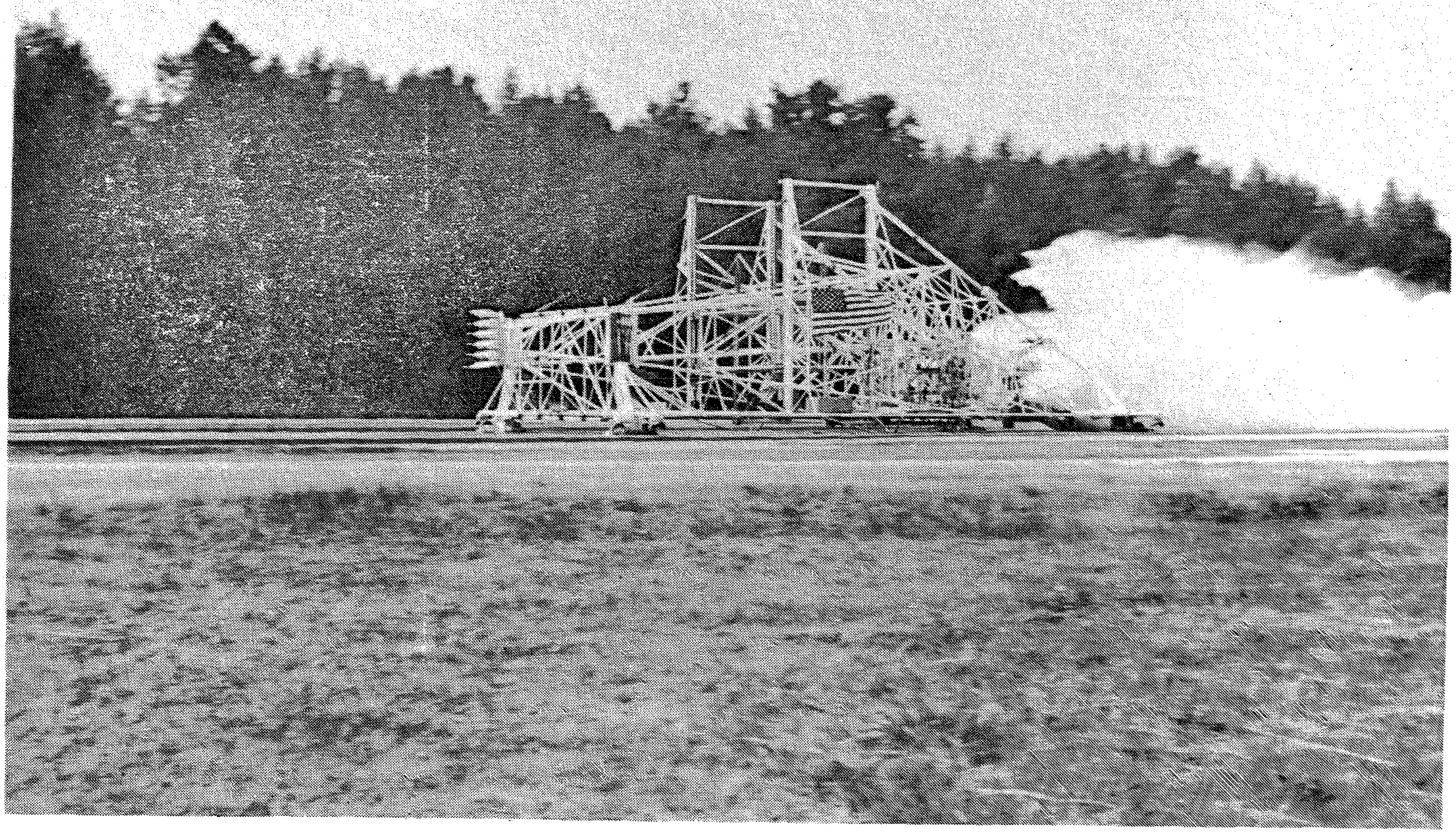
(RTOP 505-45-14)

On July 3, 1985, the new high "G" test carriage at the ALDF was catapulted to a speed of 221.6 knots (255 mph)--surpassing the maximum design speed of 220 knots. In anticipation of the Fourth of July and achieving the maximum speed, an American flag was mounted on the carriage for the high speed run. The photograph shows the carriage at high speed near the end of the acceleration pulse. Those associated with design, construction, and operation of this facility were extremely proud.

The design maximum speed was reached during checkout of the facility that called for gradual increases in captapult system pressures while monitoring stresses in selected structural tubes of the carriage. The 108,550 lb carriage was accelerated by an 18-in. diameter high pressure (3040 psi) jet of water that impinges on a turning bucket at the rear of the carriage creating a force on the carriage of over 1,800,000 lb. This force produced a peak acceleration of 17g and accelerated the carriage to 221.6 knots in 2 seconds during the first in 500 ft of travel. The carriage then coasted through an 1800 ft runway test section and was stopped in the subsequent 500 ft by an arrestment system.

Once checkout is complete, the facility will be used to conduct research on aircraft landing gear systems, tires, wheels, brakes, and runway surface treatments. Initial tests will include cornering and tire wear tests for the Shuttle Orbiter, tests of radial and H type aircraft tires, runway surface traction tests, and tests to generate data for a National Tire Modeling Program.

AIRCRAFT LANDING DYNAMICS FACILITY ACHIEVES
220 KNOT DESIGN SPEED (JULY 3, 1985)



CONTACT FORCES IN TIRE FOOTPRINT MEASURED IN DETAIL

Sharon E. Perez, William E. Howell, and John A. Tanner
Impact Dynamics Branch
Extension 2796
July 15, 1985

505-45-14-01

Research Objective

The steering committee of the National Tire Modeling Program (NTMP) has established a set of benchmark tire modeling problems and the objective of the Langley experimental tire measurement program is to develop a data base which characterizes tire responses to these problems.

Approach

Various aircraft and passenger car tires of different construction are subjected to typical inflation and static loading conditions and detailed measurements of the tire responses to these loading conditions are obtained employing instrumentation and measurement techniques designed or modified specifically for the NTMP.

Accomplishment Description

Accurate and detailed measurement of the tangential and normal contact forces of a pneumatic tire loaded on a flat surface is one of the more formidable tasks facing the participants of the National Tire Modeling Program. To facilitate these measurements the contact force transducer shown in the figure was developed specifically for NTMP. The transducer consists of ten beams mounted in a box enclosure. The bearing surface of each beam is flush with the top surface of the box. Each beam is instrumented to measure the tire contact forces normal to the surface and along two tangential axes. Thus a detailed map of the tire contact forces can be obtained by varying the transducer location within the tire contact zone.

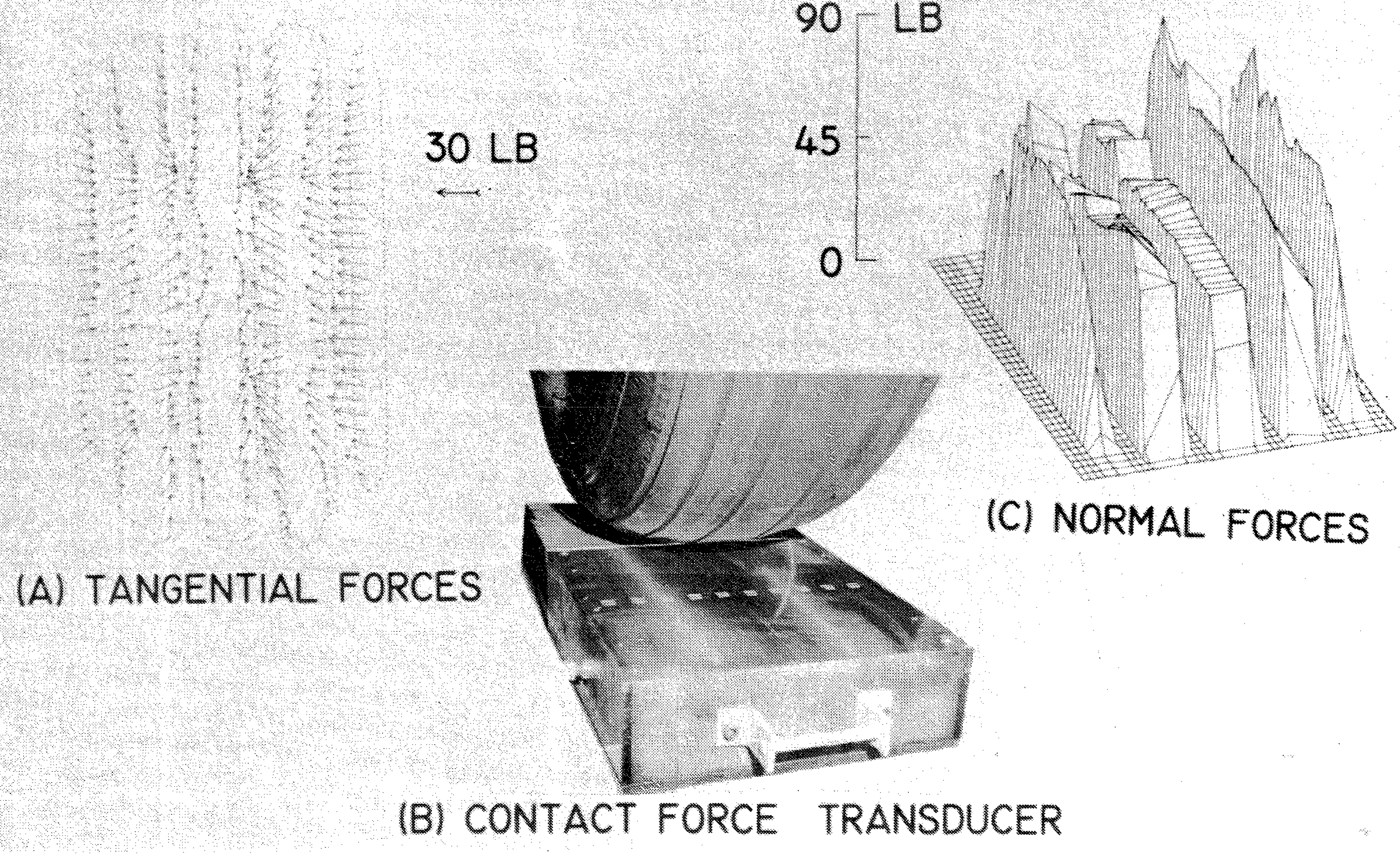
Typical maps of the tangential and normal forces within the footprint of a 40x14 aircraft tire inflated to 155 psi and subjected to a vertical load of 30 000 lbf are also presented in the figure. The tangential force map is in the form of a vector plot where the length of each vector represents the magnitude of local friction force and the direction of each vector denotes the direction of the force. The normal force map is presented in a three-dimensional format. The information contained in these plots will be used to validate various contact algorithms developed for NTMP as originally intended, but this information will also prove useful in defining the mechanism of tire squirm and its effect on tread wear and understanding other tire characteristics such as the development of alining torque in a yawed rolling tire.

Plans

Work is currently underway to develop a family of tire contact force maps for various static loading conditions. This effort will be expanded to cover low speed braking and yawed rolling conditions. When the Aircraft Landing Dynamics Facility becomes operational in the summer of 1985, this work will be expanded again to include high speed test conditions.

NASA
L-85-5906

CONTACT FORCES IN TIRE FOOTPRINT MEASURED IN DETAIL



STRUCTURAL CONCEPTS BRANCH

EFFECT OF FAILED STRUT ON ALLOWABLE LOAD OF FOUR LONGERON SPACE STATION KEEL BEAM DETERMINED

John T. Dorsey
Structural Concepts Branch, SDD
Extension 2892
October 26, 1984

(RTOP 506-53-43)

Research Objective

The objective of this research is to determine the reduction in load carrying capability of an orthogonal tetrahedral truss-beam when a critical longeron fails. The orthogonal tetrahedral truss beam is being considered for construction of the space station keel, transverse boom, keel extension and lower boom. This research will help to establish the degree of redundancy which can be expected in the space station truss structure.

Approach

A tip load is applied to a 15 bay cantilever orthogonal tetrahedral truss beam. For each value of load direction, (θ), the Euler buckling criteria given by $P_{cr} = \pi^2 EI/L^2$ is applied to each strut in the truss having a compressive load. The member in the truss which is closest to its buckling load is used to calculate on allowable tip load (the load required to buckle the critical member) for load directions between $0° \leq \theta \leq 360°$. The critical member identified for the $\theta = 0°$ case (a longeron) is then removed from the truss and new allowable tip loads calculated for the truss for the full range of θ.

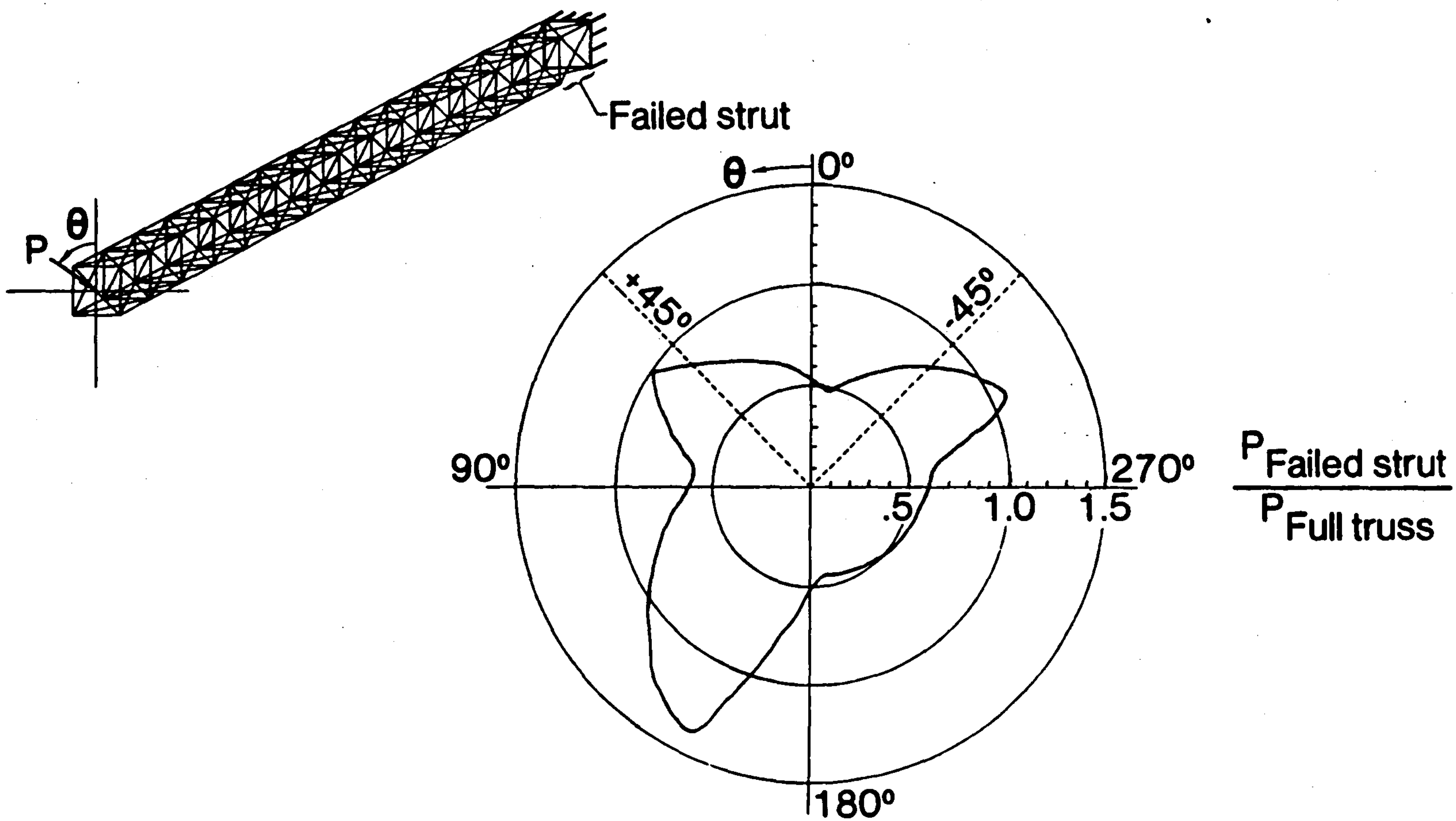
Accomplishment Description

The accompanying chart shows the ratio of the allowable tip load when a longeron fails to the allowable tip load for the full truss. Even for the worst case (at $\theta = 190°$), a truss with a failed strut can still support 44% of the allowable full truss load. The chart also shows that for loads applied at certain angles, the truss with the failed strut can support more load than the full truss. This is attributed to the redundancy provided by a four longeron truss as well as the diagonal member orientation found in the orthogonal tetrahedral truss concept.

Future Plans

In the future, other truss-beam configurations, such as the X-braced truss, will be studied for their reduction in load carrying capability due to failure of a critial longeron.

EFFECT OF FAILED STRUT ON ALLOWABLE LOAD OF FOUR LONGERON SPACE STATION KEEL BEAM DETERMINED



BASELINE ACCESS SHUTTLE FLIGHT EXPERIMENT SIMULATED IN UNDERWATER NEUTRAL BUOYANCY TESTS

Walter L. Heard, Jr. and Judith J. Watson
Structural Concepts Branch, SDD
Extensions 2608 and 2892
November 13, 1984

(RTOP 506-53-43)

Research Objective

The objectives of this research program are: (1) to perform the complete baseline ACCESS Shuttle flight experiment in simulated zero-gravity ground tests to provide data for correlation with orbital assembly rates and techniques which will be obtained from the flight test, and (2) to exercise and evaluate required hardware modifications arising from the ACCESS Critical Design Review and structural testing.

Approach

Install the ACCESS training hardware in the Neutral Buoyancy Facility at MSFC in the launch (stowed) configuration proposed for flight. Use astronaut mission specialists and engineer test subjects working in EMU space suits to perform all anticipated procedures for the baseline flight experiment (leave airlock; translate to worksite; deploy assembly fixture; assemble ten bays of truss; disassemble and stow truss; stow assembly fixture; translate to airlock).

Accomplishment Description

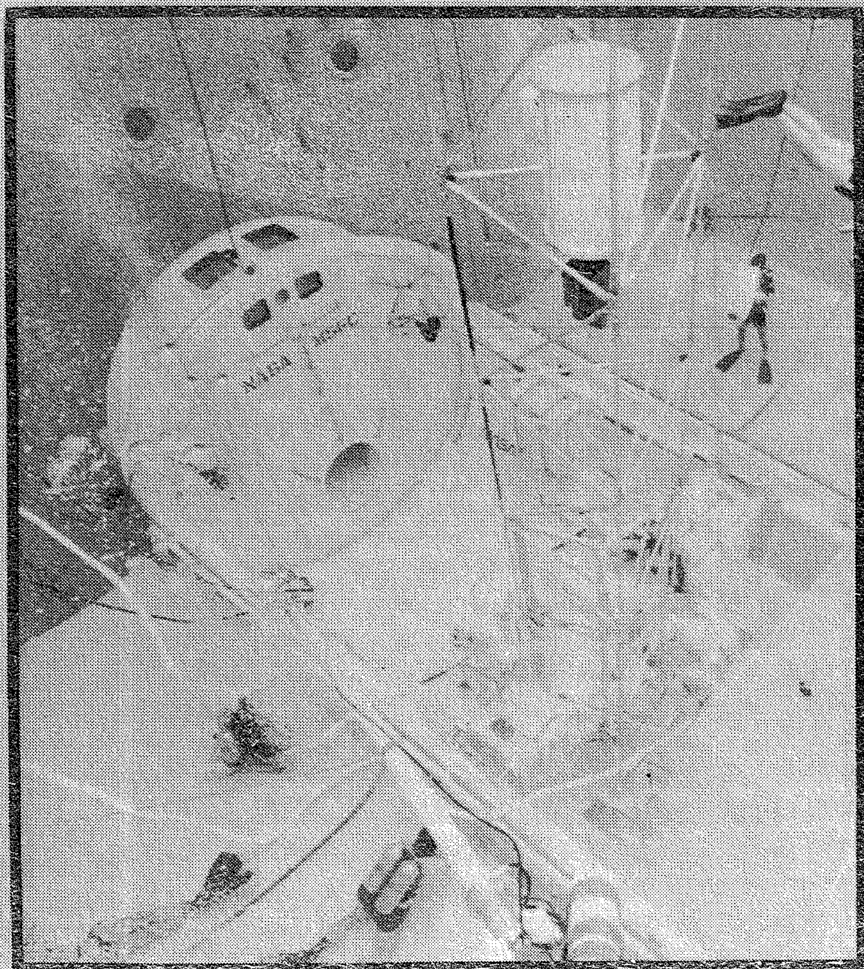
Baseline flight experiment procedures executed by astronaut and engineer test subjects. Hardware modifications checked out and found to be acceptable for flight. Complete baseline experiment accomplished in one hour and nine minutes.

Future Plans

Release engineering drawings to shops for fabrication of flight hardware. Deliver flight hardware to KSC by April 1, 1985. Plan and evaluate expanded ACCESS flight experiment if dedicated EVA approved. Expanded experiment includes assembly/disassembly by one astronaut using the remote manipulator foot restraint, replacement of struts and nodes to simulate orbital repair, and installation of simulated electrical cables. March 1985 is reserved for neutral buoyancy testing of these procedures.

NASA
L-82-11,332

BASELINE *ACCESS* SHUTTLE FLIGHT EXPERIMENT SIMULATED IN UNDERWATER NEUTRAL BUOYANCY TESTS



SIMULATED FLIGHT EXPERIMENT PERFORMED IN 1 HR. 9 MIN.

GROUND TEST DATA REQUIRED FOR CORRELATION WITH FLIGHT DATA OBTAINED

ASTRONAUT EVALUATED PROCEDURES AND HARDWARE FOUND ACCEPTABLE FOR FLIGHT

EXPANDED ACCESS SHUTTLE FLIGHT EXPERIMENT SIMULATED IN UNDERWATER NEUTRAL BUOYANCY TESTS

Walter L. Heard, Jr. and Judith J. Watson
Structural Concepts Branch, SDD
Extensions 2608 and 2892
May 8, 1985

(RTOP 506-53-43)

Research Objective

The objective of the Expanded ACCESS flight experiment is to study specific EVA tasks associated with Space Station construction. The objective of the neutral buoyancy tests is to perform these tasks in simulated zero-gravity ground tests in order to develop on-orbit construction procedures and project timelines for on-orbit performance for the flight experiment.

Approach

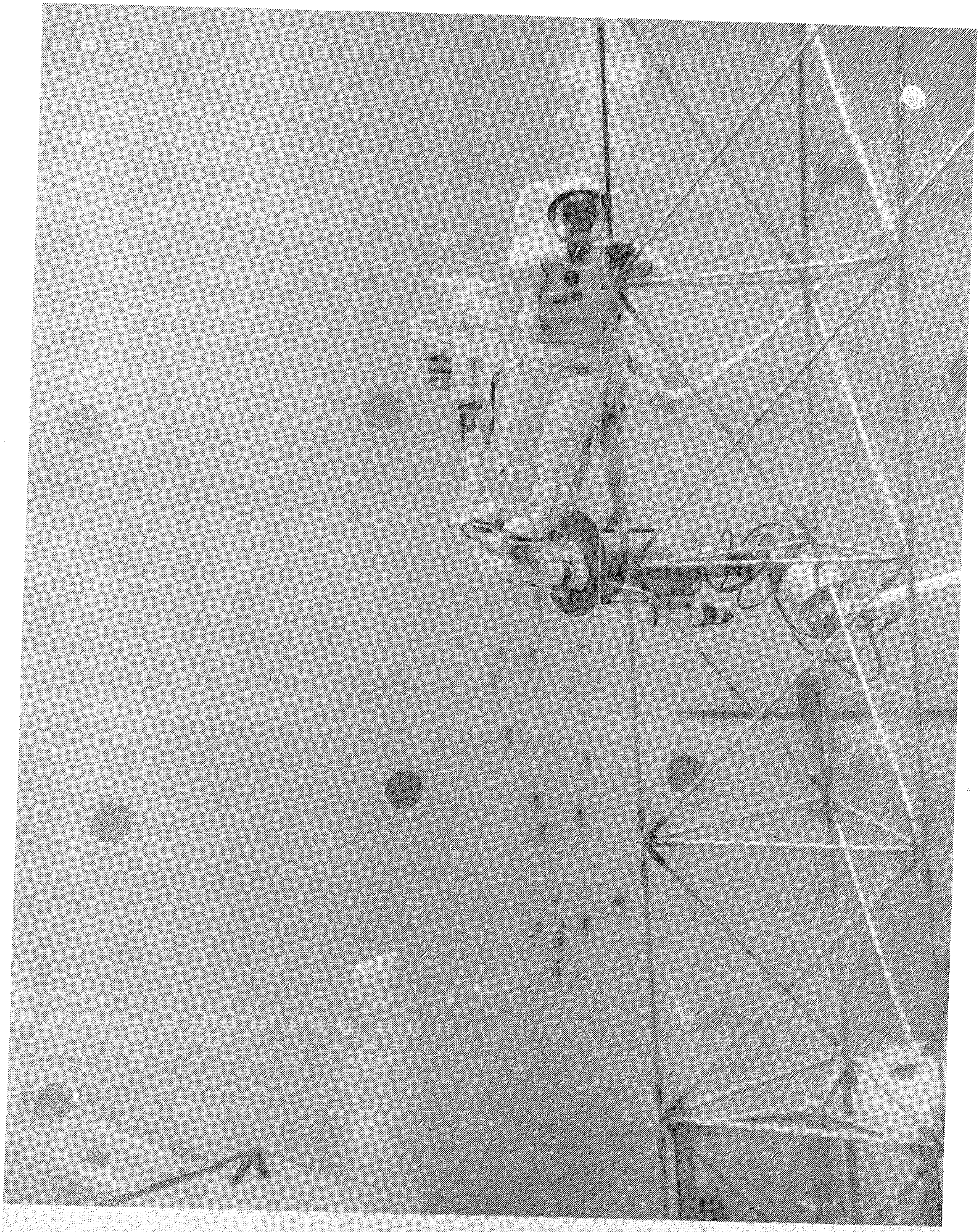
Install ACCESS training hardware in the Neutral Buoyancy Simulator (NBS) at MSFC. Use astronaut mission specialists and engineer test subjects working in EMU space suits to perform all tasks planned for the Expanded ACCESS flight experiment: (1) installation of dummy electrical cable; (2) replacement of struts and nodes to demonstrate truss repair; (3) truss assembly by one astronaut using the Remote Manipulator System (RMS) and Manipulator Foot Restraint (MFR); and (4) manual separation, manipulation, and reattachment of the assembled truss.

Accomplishment Description

All tasks were successfully executed by astronaut and engineer test subjects. Construction procedures compatible with flight RMS envelope were developed. Total time to perform Expanded ACCESS experiment was determined to be approximately two hours.

Future Plans

Complete checkout and verification of flight hardware in 1-g tests at LaRC. Ship flight hardware to KSC in June 1985 for integration onto the MPESS (Mission Peculiar Experiment Support Structure).



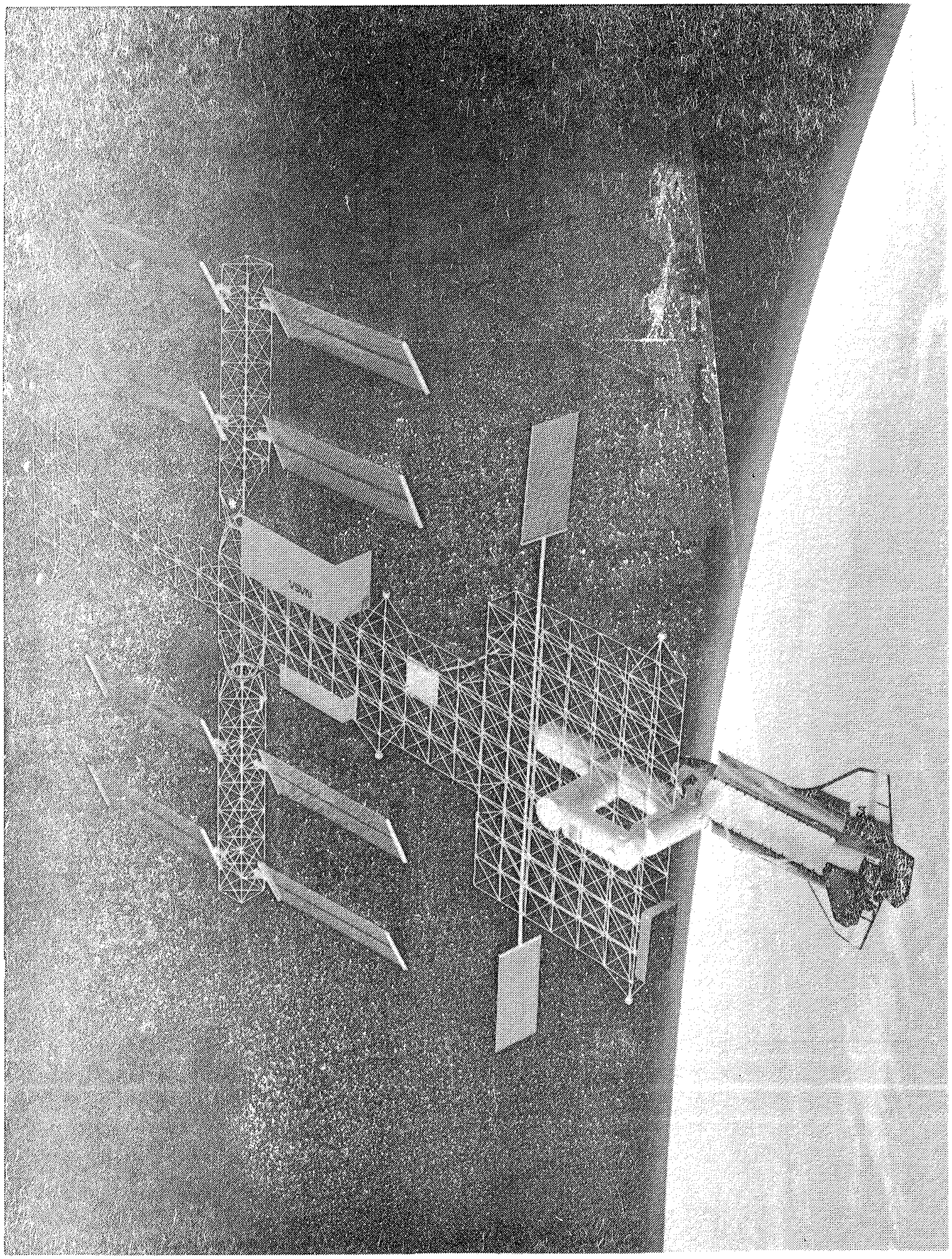
SCALE MODEL OF IOC SPACE STATION WITH 15 FOOT ERECTABLE BAYS FABRICATED

John T. Dorsey and Mark S. Lake
Structural Concepts Branch, SDD
Extensions 2892 and 2414
July 1, 1985

(RTOP 506-53-43)

A 1/72nd model of the 75 kw IOC power tower space station was fabricated in-house at the Langley Research Center. Outstanding cooperation between personnel in Langley's Fabrication Shop and Model Shop led to successful completion of the model in time for Langley's Open House. The accompanying view of the station in low Earth orbit, is a photograph of the model with an illustrated background. This rendition demonstrates the high skill level available from people in Langley's graphics and photographic sections.

This version of the space station has a bay size of 15 feet and would be built in orbit using erectable technology developed at Langley. The model proved to be the highlight of the SCB Large Space Structures/Space Station open house exhibit where it generated considerable public enthusiasm for the NASA space station project. The model has also been useful to researchers in their efforts to determine optimum locations for various space station payloads and subsystems.



NASA
L-85-6735

STRUCTURAL DYNAMICS BRANCH

ANALYTICAL MODELS OF 15-METER HOOP-COLUMN ANTENNA REFINED AND VERIFIED BY TEST

Preliminary Dynamic Test And Analysis Results

W. KEITH BELVIN
STRUCTURAL DYNAMICS BRANCH
EXTENSION 2446
JANUARY 11, 1985

RTOP 506-62-43-12

Research Objective:

Develop and verify a preliminary dynamic analytical model of the 15M Hoop Column Antenna prior to surface mesh installation.

Approach:

Develop finite element models based on design drawings and refine the models using preliminary test data. Obtain preliminary test data by modal survey of antenna at contractor site before surface mesh is installed.

Accomplishment Description:

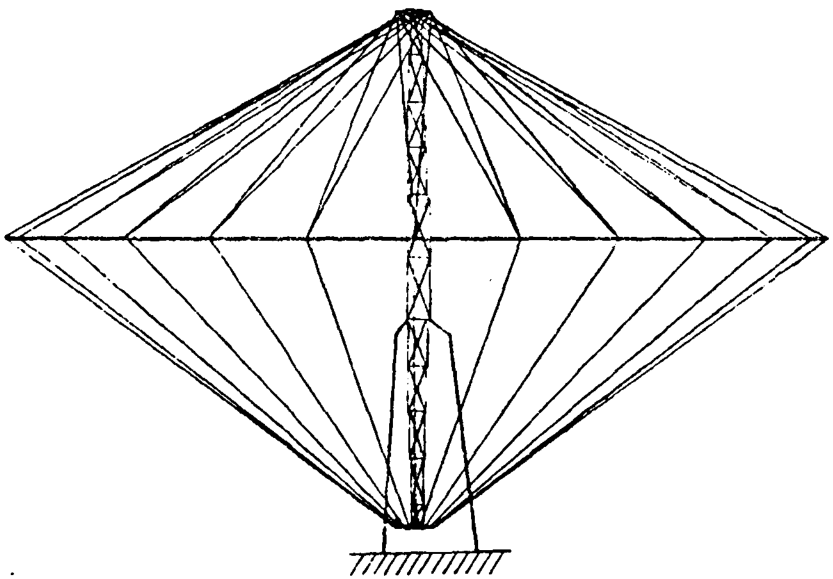
Analytical models using both NASTRAN and BUNVIS computer programs were developed for the antenna. The 15M Hoop-Column Antenna was then tested at Harris Corp., Melbourne, Florida using an impact hammer technique. The modal survey identified the frequency, damping and mode shapes of the first four modes and the frequency range of the hoop bending modes. As indicated on the attached chart, the initial analysis consistently predicted higher frequencies for the first three modes and failed to predict the fourth mode. A large source of error in the initial analysis was the inaccurate modeling of the support structure. Three six inch aluminum tubes supported the antenna from the floor as shown. The initial analysis modeled the tubes as rigid elements, whereas the refined analysis included the support flexibility. In addition, material properties were found to be in error in initial analysis due to poor documentation of the composite laminate properties. The refined analysis predicts the frequencies with more accuracy, however, the joint flexibility of the column continues to produce lower experimental frequencies. The fourth mode was found to be highly dependent on the rotational inertia of the lower column. Once this inertia was included in the refined analysis the mode was properly predicted. The chart clearly shows the importance of test data in verifying analysis assumptions and material properties.

Future Plans:

The 15M Hoop Column Antenna is scheduled to be installed in the Langley's 16M Thermal Vacuum Chamber in August, 1985 for more comprehensive tests to identify the vibration characteristics of the antenna after the surface mesh is installed. The refined analysis will be extended to include the surface mesh such that the mesh vibration modes can be predicted. Repetitive symmetry modeling will be studied using the BUNVIS analysis program.

15 M HOOP COLUMN ANTENNA

Preliminary Dynamic Test and Analysis Results



	Frequency (HZ)		
Mode	Initial Analysis	Test	Refined Analysis
1	0.105	0.068	0.084
2	2.02	0.785	1.00
3	4.73	1.36	1.72
4	----	3.13	3.21

- Preliminary Test Conducted At Contractor Site
- Advanced Analysis Methods Being Applied
- Delivery To LaRC For Dynamic Tests In Aug. '85

UNIQUE STRUCTURAL DYNAMICS MEASUREMENTS
ACQUIRED FROM OAST-1 EXPERIMENT

M. LARRY BRUMFIELD
RICHARD S. PAPPA
STRUCTURAL DYNAMICS BRANCH
EXTENSION 3196
JANUARY 11, 1985

RTOP 506-62-49-01

Research Objective:

To measure dynamic responses of a large solar array using a photogrammetric technique during the MSFC/OAST-1 Solar Array Flight Experiment.

Approach:

The shuttle closed-circuit television system was used on orbiter flight 41-D to record video images of the solar array dynamic responses to excitation inputs from orbiter VRCS jets. Post-flight analysis of these video recordings is being conducted using a special in-house designed and built system which tracks the position change of specific targets from frame to frame of the video tape. Analyzed video data from four TV cameras are combined using in a photogrammetric triangulation computer program to determine a three dimensional displacement-time history of the solar array in shuttle coordinates. This motion history is then analyzed using appropriate system identification techniques to determine modal frequency and damping characteristics of the array in response to input excitations.

Accomplishment Description:

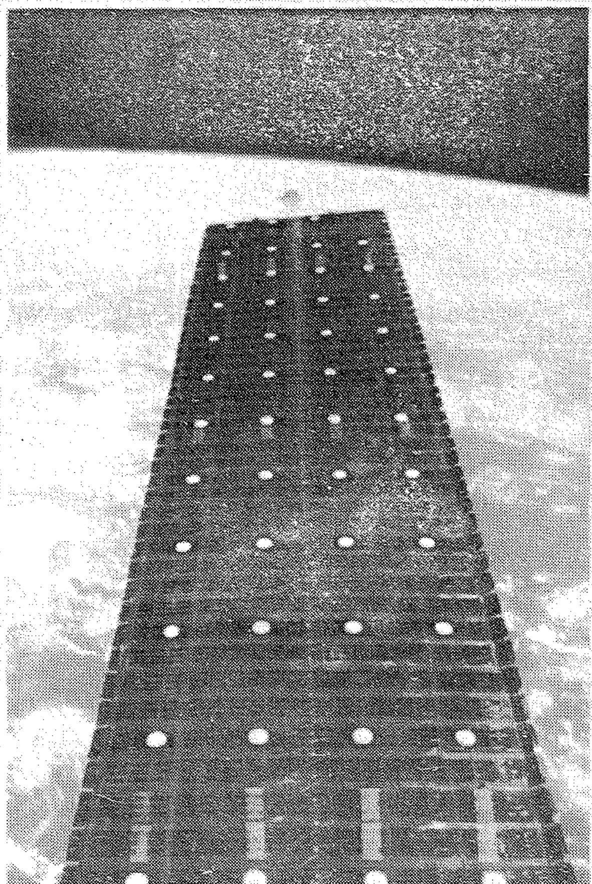
Analysis of video recordings from three of the seven orbital tests has been completed. Preliminary results of triangulation and system identification analyses show smaller displacements than predicted but measured frequencies very close to preflight predictions. For the 100 percent deployed, out-of-plane test, measured first-mode damping was 3.5 percent compared to 0.5 percent used in pre-flight predictions. Peak-to-Peak displacements of up to 19 inches at the tip of the 100-foot tall array were measured with an error of less than 0.1 inch. Video data shows the array has a residual, steady-state motion with a tip displacement of approximately 0.7 inch. In addition, there is an unexpected, marked transverse bowing that is most extreme in darkness but becomes less pronounced, sometimes nearly flat, in daylight.

Future Plans:

Analysis of flight video data will continue to completion. Photogrammetric analyses and system identification studies of all data will be performed. Results will be presented at the 26th SDM Conference, April 15-17, 1985.

NASA
L-85-727

UNIQUE STRUCTURAL DYNAMICS MEASUREMENTS ACQUIRED FROM OAST-1 EXPERIMENT



Photogrammetry Analysis Applied to Recorded Video Images

Preliminary Analysis Conducted on 125 of Over 900 Target Time Histories

- Measured Frequencies Very Close to Predictions
- Measured First-Mode Damping (3.5%) Higher Than Anticipated (0.5%)
- Unexpected, Marked Transverse Bowing Occurs During Darkness
- Residual, Steady-State Motion Observed
- Measured Displacement Errors Less Than 0.1 inch at 100 ft

Detailed Data Analysis Under Way

PRVT RESIDUAL STRENGTH TESTS INDICATE NO PERFORMANCE DEGRADATION DUE TO LONG TERM DURABILITY TESTING

Osvaldo F. Lopez
Structural Mechanics Branch, SDD
Extension 3179
March 21, 1985

(RTOP 534-06-23)

Research Objective

To determine the effects of long-term durability testing that simulates flight service conditions on the residual strength of large graphite-epoxy aircraft structural spar and cover panel components.

Approach

The Lockheed Corporation fabricated 22 cover-panel and 22 spar components for the NASA/ACEE L-1011 vertical fin Production Readiness Verification Test (PRVT) program. Ten of each component were tested to failure to determine their static strength soon after fabrication and to provide control or reference data. The remaining specimens were placed in environmental chambers and subjected to long term durability testing to simulate flight service conditions. Eleven of these environmentally conditioned specimens were statically tested to failure at Langley Research Center to determine the effects of simulated flight service on their residual strength.

Accomplishment Description

The attached chart illustrates the results of the spar specimen residual-strength tests. The left photograph shows a typical spar specimen constructed of T300/5208 graphite-epoxy tape, and the center photograph shows a typical failure mode. Failure was caused by local delaminations which initiated at the edge of the middle access hole and subsequently propagated to both edges of the the specimen. Plotted on the right are the failure loads for the control specimens and the environmentally-conditioned specimens. The left graph represents the failure loads of ten control specimens. The remaining graphs show the failure loads of the conditioned specimens. A total of five conditioned specimens were tested, two 10 year and three 20 year conditioned specimens. The results indicate that all five conditioned spar specimens failed within the failure range or slightly above the average failure load of the control specimens. Similar results were obtain for the cover-panel specimens. The results of the PRVT program indicate that the structural behavior of the specimens tested were unaffectd by long term durability testing.

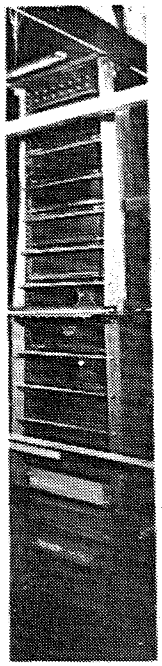
Future Plan

To conduct an analytical study of both spar and cover-panel specimens using a finite element procedure and to conduct damage-tolerance tests on the remaining specimens.

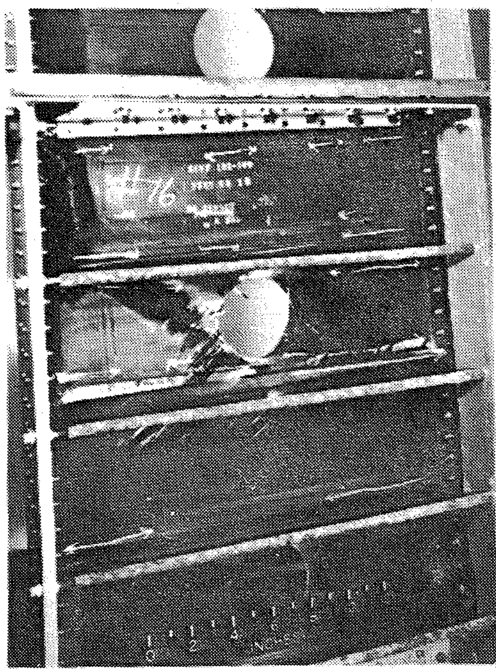
NASA
L-85-2469

PRVT RESIDUAL STRENGTH TESTS INDICATE NO PERFORMANCE DEGRADATION

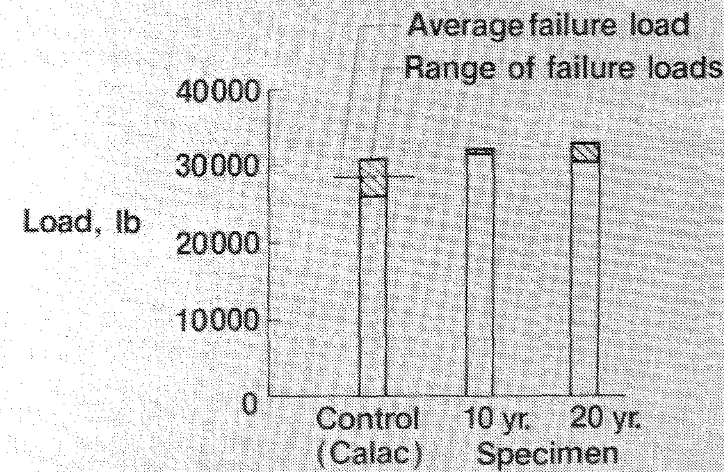
L-1011 vertical fin spar



Failure mode



Residual strength test results



NEW PROCEDURE IMPROVES ANTENNA SURFACE ACCURACY

W. Keith Belvin
Harold H. Edighoffer
Structural Dynamics Branch, SDD
Extension 2446
July 15, 1985

RTOP 506-62-43-12

Research Objective

To develop methods for improving the surface accuracy and hence the Radio Frequency (RF) performance of large space antennas.

Approach

Finite element analysis and least squared error analysis are used to compute a set of surface control cable length changes that minimize the error between the fabricated and the designed surface locations.

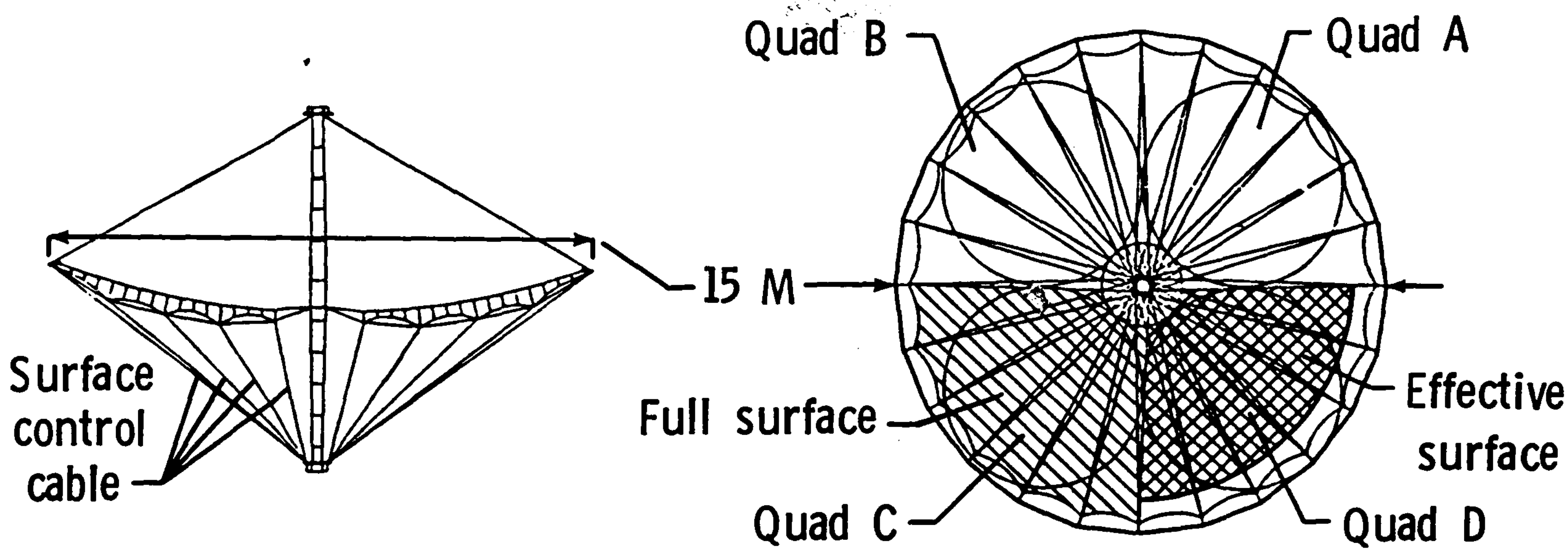
Accomplishment Description

The 15 meter Hoop/Column antenna has been fabricated at Harris Corporation and delivered to Martin Marietta, Denver for RF testing. Metric Camera measurements of 888 surface targets showed the antenna fabrication tolerances resulted in an average surface roughness of 0.147 inches RMS. This surface roughness would significantly degrade the RF performance of the antenna, consequently, a surface adjustment procedure was developed. A large finite element model of the antenna was used to assemble a sensitivity matrix which predicts the displacement of 888 surface targets due to changes in length of the 96 surface control cables. This sensitivity matrix was used to calculate a set of surface control cable length changes necessary to minimize the error between the measured target locations and the design target locations. As shown on the attached chart, the RMS error was reduced by an average of 23 percent for the full surface and 32 percent for the effective surface. The effective surface is a subset of the full surface in that it does not include the outermost portion of the mesh. The outermost part of the surface is not illuminated by the feed, hence, its surface accuracy does not significantly effect the RF performance. The chart shows that the new predicted RMS agrees well with the new measured RMS except for quadrant D. This discrepancy was found to be due to one cable not being adjusted properly. This cable has now been adjusted and the RF tests are being performed. Preliminary RF data shows the antenna to perform near the design gain and sidelobe levels.

Future Plans

A weighting of the surface targets will be performed to account for the RF power distribution over the antenna. A set of cable adjustments will be computed and implemented using the weighted target locations to determine if the RF performance can be improved further. In addition, a study is planned of alternate surface control cable designs that improve the controllability of the surface.

NEW PROCEDURE IMPROVES ANTENNA SURFACE ACCURACY



- Least squares error method used to minimize error between measured surface and desired surface
- Computed 96 surface control cable length changes

Quad	Original measured RMS		New predicted RMS		New measured RMS	
	Full Surface	Effective Surface	Full Surface	Effective Surface	Full Surface	Effective Surface
A	0.144	0.120	0.106	0.076	0.108	0.075
B	0.133	0.107	0.112	0.079	0.119	0.081
C	0.153	0.142	0.114	0.095	0.116	0.094
D	0.159	0.132	0.104	0.078	0.108	0.091

STRUCTURAL MECHANICS BRANCH

SIMPLE HIGHER-ORDER SHEAR DEFORMATION THEORY DEVELOPED FOR LAMINATED COMPOSITE PLATES

Norman F. Knight, Jr.
Structural Mechanics Branch, SDD
Extension 3179
October 26, 1984
(RTOP 505-33-53)

Research Objective

To develop a simple, variationally consistent, higher-order theory for laminated composite plates that accounts for a parabolic distribution of the transverse shearing strains through the thickness of the plate.

Approach

The approach developed by Professor J. N. Reddy at V.P.I. and S.U. under NASA Grant NAG-1-459 is to assume a displacement field that satisfies the conditions that the transverse shear stresses vanish on the plate surfaces and be nonzero elsewhere. The inplane displacements are expanded as cubic functions of the thickness coordinate and the transverse displacement is constant through the plate thickness. The equilibrium equations are derived using the principle of virtual displacements and then used to develop a two-dimensional thin plate finite element.

Accomplishment Description

An improved shear deformation theory (HSDT) that gives parabolic distribution of the transverse shear strains has been developed for thin plates. The theory contains the same number of dependent variables as a Mindlin-type first-order shear deformation theory (FSDT), but results in more accurate prediction of the deflections and stresses, and satisfies the zero tangential traction boundary conditions on the surfaces of the plate. The present theory does not require the use of shear correction factors common to first-order theories. The transverse shear stress σ_{xz} distribution through the thickness of a cross-ply laminate at the center of the square plate (point C) obtained using a displacement finite element formulation is shown in the figure. Using the present theory, a parabolic distribution is obtained across each layer. Using a first-order shear deformation theory, the inplane displacements are assumed to vary linearly through the thickness which results in a constant transverse shear stress in each layer. As such, the through-the-thickness distribution is more qualitatively correct using the present theory than the FSDT when compared to the three-dimensional elasticity solution without increasing the number of dependent variables. The difference between the present theory and the elasticity solution is attributed to the fact that stress continuity across each layer interface is not imposed in a displacement formulation.

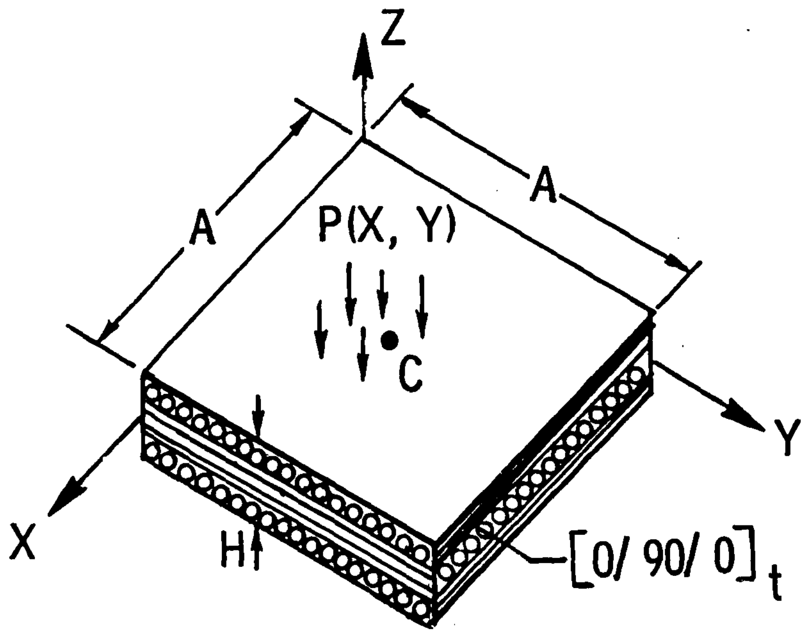
Future Plans

To use a mixed finite element formulation to address the stress continuity issue. To extend the applications to the nonlinear analysis of laminated composite plates and to develop a higher-order transverse shear deformation theory for shells.

NASA
L-84-10,557

SIMPLE HIGHER-ORDER SHEAR DEFORMATION THEORY DEVELOPED FOR LAMINATED COMPOSITE PLATES

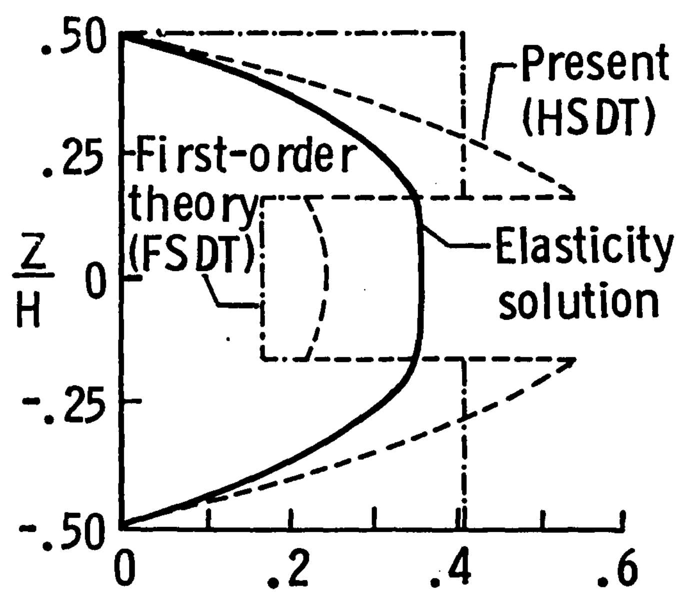
- Variationally consistent theory
- Formulation compatible with FSDT-based finite element codes
- Stress-free boundary conditions satisfied



A/ H = 10

$$P(X, Y) = P_0 \sin\left(\frac{\pi X}{A}\right) \sin\left(\frac{\pi Y}{A}\right)$$

Through-the-thickness distribution of transverse shear stress σ_{XZ} at point C



Normalized shear stress $\frac{\sigma_{XZ} H}{P_0 A}$

81

THIN-WALLED FILAMENT-WOUND STIFFENED CYLINDER TEST PREPARATIONS UNDERWAY

Michael P. Nemeth and James H. Starnes, Jr.
Structural Mechanics Branch, SDD
Extensions 4585 and 2552
March 21, 1985

(RTOP 505-33-33)

Research Objective

To conduct a preliminary experiment to identify the response and failure characteristics and potential problems associated with the analysis and design of thin-walled filament-wound stiffened composite cylinders loaded in flat-end compression.

Approach

A potentially inexpensive way to manufacture composite aircraft fuselage structure components appears to be a method using filament winding. Past studies of filament-wound pressure vessels have indicated that filament winding is an attractive way to manufacture tension-loaded structures. There has been little experience to date with other loading conditions for thin-walled filament-wound structures. Of the various loads applied to aircraft fuselages, destabilizing flat-end compression loads may cause undesirable structural response associated with the nature of the filament-winding manufacturing process. The advantages associated with reduced manufacturing costs of filament-wound structures may be offset by increases in detrimental effects caused by inhomogeneity and imperfections. To identify the importance of these effects, high precision measurement of the skin laminate nonuniformities and initial geometry of a representative structure have been made. Analysis and full-scale testing to failure are planned.

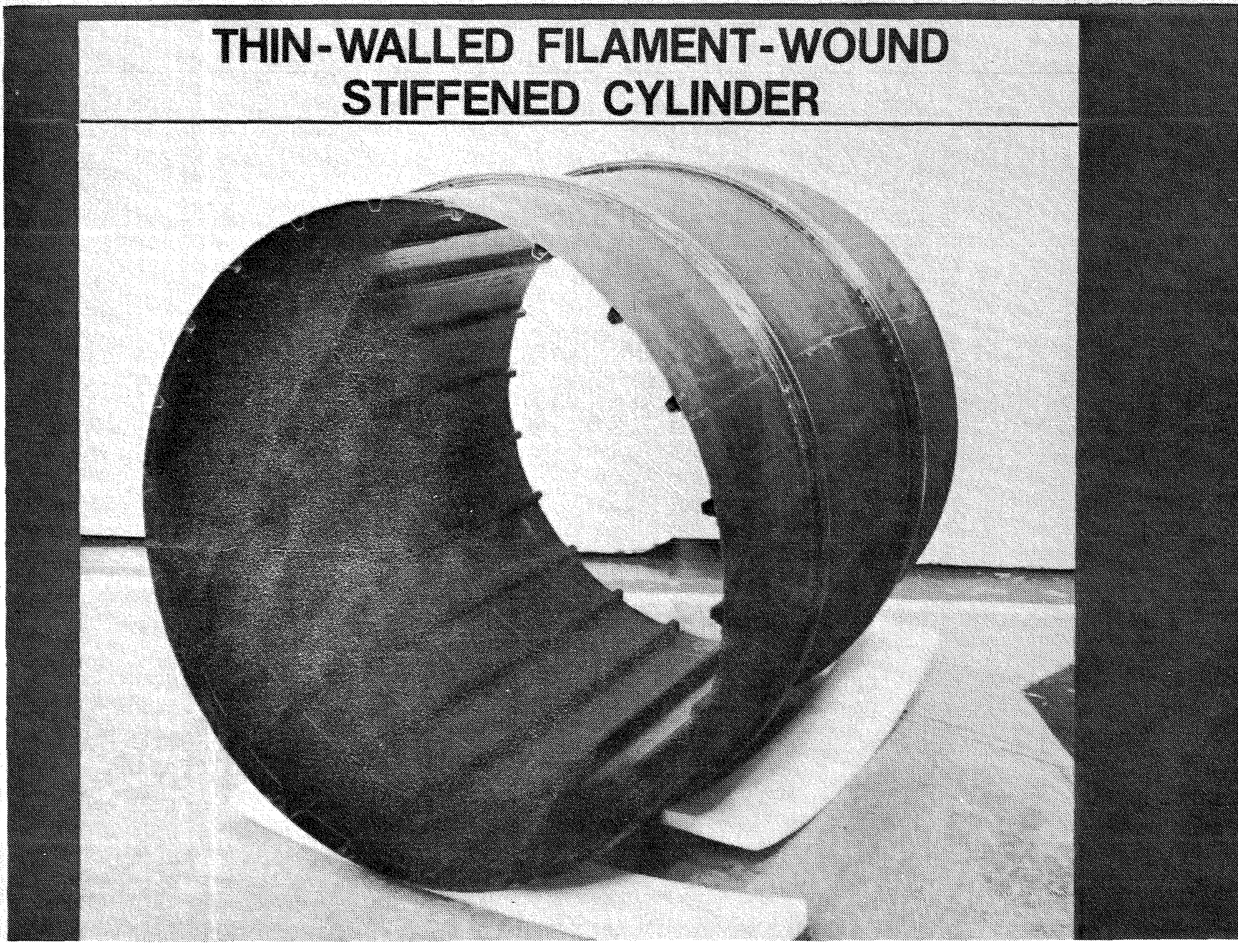
Accomplishment Description

A ring- and stringer-stiffened filament-wound cylinder has been obtained from the Lockheed-Georgia Company for testing, in return for the test data. Mechanical hardware and computer software were developed for measuring the initial geometry of the cylinder and geometric imperfection surveys have been made. Ultrasonic C-scans have also been made to determine the extent of manufacturing and transportation damage. Final stages of instrumentation and preparation for testing are underway.

Future Plans

Conduct the experiment and provide a test-analysis correlation using the STAGS-C1 computer code with the measured geometric imperfection data.

NASA
L-84-12,171



COMPOSITE COMPRESSION PANEL DAMAGE-CONTAINMENT CONCEPT DEMONSTRATED

Jerry G. Williams
Structural Mechanics Branch, SDD
Extension 4052
May 24, 1985

(RTOP 534-06-23)

Research Objective

To develop advanced composite structural concepts which arrest propagating damage under compression loading; to understand the associated engineering principles; and to demonstrate promising concepts by test.

Approach

One damage-containment concept developed and demonstrated in prior Langley Research Center research with flat unstiffened panels involves making the skin plies discontinuous. The discontinuity arrests the delamination mode of damage propagation. The principle was further studied by evaluating its potential in a realistic stiffened panel configuration designed and fabricated for NASA under Contract NAS1-15949 by the Lockheed Georgia Company. The panel was subjected to low speed impact damage and then tested to failure to determine its residual strength.

Accomplishment Description

The graphite-epoxy panel shown in the figure is designed to meet representative transport aircraft stiffness requirements and to carry 20,000 lb/inch compression loading at an axial strain of 0.0045. To help arrest propagating damage, the panel has two longitudinal discontinuities in the skin. A bolted splice (four rows of bolts) is used to carry the shear loads across the discontinuity. The panel was impacted in the skin between the third and fourth stiffeners from the left with 26.7 ft-lb of energy while loaded to 17,400 lb/inch compression load. The damage propagated to the boundaries indicated by the white paint, however, the panel held the load without failure. In a subsequent residual strength test the panel carried 20,600 lb/inch at failure thus exceeding the design requirements. These results indicate that structural design concepts can be developed for graphite-epoxy panels that will arrest local damage propagation.

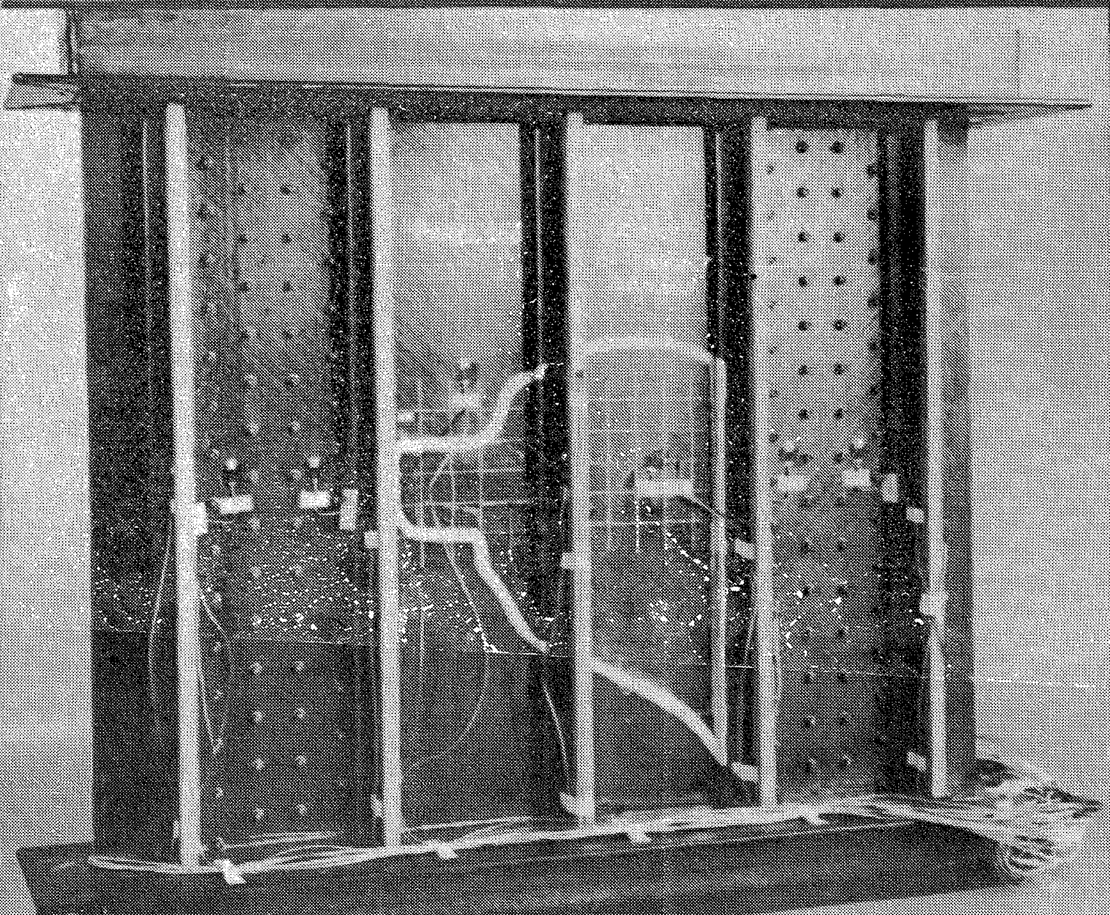
Future Plans

One additional test will be conducted on this configuration using a longer panel to evaluate better the load redistribution effects after damage has occurred. These results and test results from other damage-containment configurations will be described in a future publication on damage-containment concepts for compression-loaded graphite-epoxy panels.

NASA
L-84-12,170

DAMAGE CONTAINMENT PANEL FOLLOWING IMPACT

Stiffener side



Impact condition

- 26.7 ft-lb
- Strain = .004
- N_x = 17400 lb/in

Residual strength

- ε = .0047
- N_x = 20600 lb/in

VIII PUBLICATIONS AND PRESENTATIONS

VIII PUBLICATIONS AND PRESENTATIONS

The FY 1985 accomplishments resulted in a number of publications and presentations. They are listed below as Formal Reports; Quick-Release Technical Memorandums; Contractor Reports; Journal Articles and Other Publications; Meeting Presentations; Technical Talks; Computer Programs; Tech Briefs; and Patents.

Formal Reports

1. Carden, H. D.: Full-Scale Crash-Test Evaluation of Two Load-Limiting Subfloors for General Aviation Airframes. NASA TP-2380, December 1984

2. Daugherty, R. H.: Impact Studies of a 1/3-Scale Model of an Air Cushion Vehicle. NASA TM-86360, April 1985

3. Hayduk, R. J.; and Noor, A. K. (Compilers): Research in Structures and Dynamics - 1984. NASA CP-2335, October 1984

4. Nemeth, M. P.: A Buckling Analysis for Rectangular Orthotropic plates With Centrally Located Cutouts. NASA TM-86263, December 1984

5. Noor, A. K.; Andersen, C. M.; and Tanner, J. A.: Mixed Models and Reduction Techniques for Large Rotation, Nonlinear Analysis of Shells of Revolution With Application to Tires. NASA TP-2343, October 1984

6. Rhodes, M. D.; and Mikulas, M. M., Jr.: Deployable Controllable Geometry Truss Structure. NASA TM-86366, June 1985

7. Watson, J. J.; Heard, W. L., Jr.; and Jensen, J. K.: Swing-Arm Beam Erector (SABER) Concept for Single Astronaut Assembly of Space Structure. NASA TP-2379, March 1985

Quick-Release Technical Memorandums

8. Bales, K. S.: Structures and Dynamics Division - Research and Technology Plans for FY 1985 and Accomplishments for FY 1984. NASA TM-86417, April 1985

9. Card, M. F.; Anderson, M. S.; and Walz, J. E.: Dynamic Response of a Flexible Space Beam. NASA TM-86441, May 1985

10. Carden, H. D.: Impact Dynamics Research on Composite Transport Structures. NASA TM-86391, March 1985

11. Fulton, R. E.; and Salley, G. C.: IPAD: A Unique Approach to Government/Industry Cooperation for Technology Development and Transfer. NASA TM-86422, June 1985

12. Housner, J. M.: Structural Dynamics Model and Response of the Deployable Reference Configuration Space Station. NASA TM-86386, May 1985

13. Jackson, K. E.: Friction and Wear Behavior of Aluminum and Composite I-Beam Stiffened Airplane Skins. NASA TM-86418, AVSCOM TM 85-B-2, June 1985

14. Knight, N. F., Jr.; and Stroud, W. J.: Computational Structural Mechanics: A New Activity at the NASA Langley Research Center. NASA TM-87612, September 1985

15. McComb, H. G., Jr.: Large Deflections of a Cantilever Beam Under Arbitrarily Directed Tip Load. NASA TM-86442, May 1985

16. McGowan, P. E.; and Housner, J. M.: Nonlinear Dynamic Analysis of Deploying Flexible Space Booms. NASA TM-87617, September 1985

17. Mikulas, M. M., Jr.; Croomes, S. D.; Schneider, W.; Bush, H. G.; Nagy, K.; Pelischek, T.; Lake, M. S.; and Wesselski, C.: Space Station Truss Structures and Construction Considerations. NASA TM-86338, January 1985

18. Mikulas, M. M., Jr.; Wright, A. S., Jr.; Bush, H. G.; Watson, J. J.; Dean, E. B.; Twigg, L. T.; Rhodes, M. D.; Cooper, P. A.; Dorsey, J. T.; Lake, M. S.; Young, J. W.; Stein, P. A.; Housner, J. M.; and Ferebee, M. J., Jr.: Deployable/Erectable Trade Study for Space Station Truss Structures. NASA TM-87573, July 1985

19. Ransom, J. B.; and Fulton, R. E.: Concurrent Implementation of the Crank-Nicolson Method for Heat Transfer Analysis. NASA TM-86448, June 1985

20. Waters, W. A., Jr.; and Williams, J. G.: Failure Mechanisms of Laminates Transversely Loaded by Bolt Push-Through. NASA TM-87603, September 1985

Contractor Reports

21. Arnold, R. R.; and Parekh, J. C.: Theoretical Prediction of Ultimate Strength of Composite Curved Frame Members. NASA CR-172441, October 1984 (NAS1-17569 Anamet Laboratories, Inc.)

22. Crockett, T. W.; and Knott, J. D.: System Software for the Finite Element Machine. NASA CR-3870, February 1985 (NAS1-16000 Kentron International, Inc.)

23. Fuh, J-S.; and Berman, A.: Automated Dynamic Analytical Model Improvement for Damped Structures. NASA CR-177945, September 1985 (NAS1-15805 Kaman Aerospace Corporation)

24. Miller, R. E., Jr.: IPAD - Integrated Programs for Aerospace-Vehicle Design. NASA CR-3890, May 1985 (NAS1-14700 Boeing Commercial Airplane Company)

25. Post, D.; Czarnek, R.; Joh, D.; and Wood, J.: Deformation Measurements of Composite Multi-Span Beam Shear Specimens by Moire Interferometry. NASA CR-3844, November 1984 (NAG1-359 Virginia Polytechnic Institute and State University)

26. Shane, S. J.: Design and Testing of an Energy-Absorbing Crewseat for the F/FB-111 Aircraft, Volume I - Final Report. NASA CR-3916, August 1985 (NAS1-17387 Simula, Inc.)

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29. Anderson, M. S.; and Williams, F. W.: Buckling of Simply Supported Plate Assemblies Subject to Shear Loading. Book entitled: Aspects of the Analysis of Plate Structures - A Volume in honor of W. H. Wittrick, September 1985, p. 39-50

30. Barnes, A. G.; and Yager, T. J.: Simulation of Aircraft Behavior on and Close to the Ground. AGARDograph, January 1985, AGARD-AG-285, p. 1-B21

31. Belvin, W. K.: Analytical and Experimental Vibration and Buckling Characteristics of a Pretensional Stayed Column. Journal of Spacecraft and Rockets, Volume 21, No. 5, September - October 1984, p. 456-462

32. Belvin, W. K.: Vibration Characteristics of Hexagonal Radial Rib and Hoop Platforms. Journal of Spacecraft and Rockets, Volume 22, No. 4, July - August 1985, p. 450-456

33. Chun, H. M.; Turner, J. D.; and Juang, J-N.: Disturbance-Accommodating Tracking Maneuvers of Flexible Spacecraft. Journal of the Astronautical Sciences, Volume 33, No. 2, April - June 1985, p. 197-216

34. Cooper, P. A.; Miserentino, R.; Sawyer, J. W.; and Leatherwood, J. D.: Effect of Simulated Mission Loads on Orbiter Thermal Protection System Undensified Tiles. Journal of Spacecraft and Rockets, Volume 21, No. 5, September - October 1984, p. 441-447

35. Fichter, W. B.: Reduction of Root-Mean-Square Error in Faceted Space Antennas. AIAA Journal, Volume 22, No. 11, November 1984, p. 1679-1684

36. Greene, W. H.: Effects of Random Member Length Errors on the Accuracy and Internal Loads of Truss Antennas. Journal of Spacecraft and Rockets, Volume 22, No. 5, September - October 1985, p. 554-559

37. Guardal, Z.; Haftka, R. T.; and Starnes, J. H., Jr.: The Effects of Slots on the Buckling and Postbuckling Behavior of Laminated Plates. Journal of Composites Technology and Research, Volume 7, No. 3, 1985, p. 82-87

38. Juang, J-N.: Optimal Design of a Passive Vibration Absorber for a Truss Beam. Journal of Guidance, Control, and Dynamics, Volume 7, No. 6, November - December 1984, p. 733-739

39. Juang, J-N.: Optimal Design of a Passive Vibration Absorber for a Truss Beam. Aeronautics/Space Technology, July 1985

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41. Juang, J-N.; and Pappa, R. S.: An Eigensystem Realization Algorithm for Modal Parameter Identification and Model Reduction. Journal of Guidance, Control, and Dynamics, Volume 8, No. 5, September - October 1985, p. 620-627

42. Pappa, R. S.; and Juang, J-N.: Galileo Spacecraft Modal Identification Using an Eigensystem Realization Algorithm. Journal of the Astronautical Sciences, Volume 33, No. 1, January - March 1985, p. 15-33

43. Shuart, M. J.; and Williams, J. G.: Investigating Compression Failure Mechanisms in Composite Laminates With a Transparent Fiberglass-Epoxy Birefringent Material. Experimental Techniques, Volume 8, No. 11, November 1984, p. 24-25

44. Sirlin, S. W.; Longman, R. W.; and Juang, J-N.: Identifiability of Conservative Linear Mechanical Systems. The Journal of Astronautical Sciences, Volume 33, No. 1, January - March 1985, p. 95-118

45. Starnes, J. H., Jr.; Knight, N. F., Jr.; and Rouse, M.: Postbuckling of Selected Flat Stiffened Graphite-Epoxy Panels Loaded in Compression. AIAA Journal, Volume 23, No. 8, August 1985, p. 1236-1246

46. Stein, M.: Analytical Results for Postbuckling Behavior of Plates in Compression and in Shear. Book entitled: Aspects of the Analysis of Plate Structures - A Volume in honor of W. H. Wittrick, September 1985, p. 205-223

47. Stein, M.: Postbuckling of Long Orthotropic Plates in Combined Shear and Compression. AIAA Journal, Volume 23, No. 5, May 1985, p. 788-794

48. Stein, M.: Postbuckling of Long Orthotropic Plates Under Combined Loading, AIAA Journal, Volume 23, No. 8, August 1985, p. 1267-1272

49. Turner, J. D.; Chun, H. M.; and Juang, J-N.: An Analytic Solution for the State Trajectories of a Feedback Control System. Journal of Guidance, Control, and Dynamics, Volume 8, No. 1, January - February 1985, p. 147-148

50. Williams, F. W.; and Anderson, M. S.: Buckling and Vibration Analysis of Shear-Loaded Prismatic Plate Assemblies With Supporting Structures, Utilizing Symmetric or Repetitive Cross-Section. Book entitled: Aspects of the Analysis of Plate Structures - A Volume in honor of W. H. Wittrick, September 1985, p. 51-71

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51. Alfaro-Bou, E.; Fasanella, E. L.; and Williams, M. S.: Crashworthy Design Considerations for General Aviation Seats. Presented at the 1985 SAE General Aviation Aircraft Meeting and Exposition, April 15-19, 1985, Wichita, Kansas. SAE Paper No. 850855

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53. Bainum, P. M.; Woodard, S. E.; and Juang, J-N.: The Development of Optimal Control Laws for Orbiting Tethered Platform Systems. Presented at the AAS/AIAA Astrodynamics Specialist Conference, August 12-15, 1985, Vail, Colorado. AAS Paper No. 85-360

54. Boitnott, R. L.; Johnson, E. R.; and Starnes, J. H., Jr.: A Nonlinear Analysis of Infinitely Long Graphite-Epoxy Cylindrical Panels Loaded With Internal Pressure. Presented at the AIAA, ASME, et al., 26th Structures, Structural Dynamics, and Materials Conference, April 15-17, 1985, Orlando, Florida. AIAA Paper No. 85-0770-CP

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57. Brumfield, M. L.; Pappa, R. S.; Miller, J. B.; and Adams, R. R.: Orbital Dynamics of the OAST-1 Solar Array Using Video Measurements. Presented at the AIAA, ASME, et al., 26th Structures, Structural Dynamics, and Materials Conference, April 15-17, 1985, Orlando, Florida. AIAA Paper No. 85-0758-CP

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16. Abstract

This paper presents the Objectives, FY 1986 Plans, Approach, and FY 1986 Milestones for the Structures and Dynamics Division's research programs. FY 1985 Accomplishments are presented where applicable. This information is useful in program coordination with other governmental organizations in areas of mutual interest.

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